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China Report

SCIENCE AND TECHNOLOGY

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CHINA REPORT

SCIENCE AND TECHNOLOGY

CONTENTS

PEOPLE'S REPUBLIC OF CHINA

ABSTRACTS

TECHNOLOGY REVOLUTION SEEN AS DEVELOPMENT CHALLENGE

Beijing RED FLAG in Chinese No 20, 21 Oct 84 pp 42-44

[Article by Zhu Tiezhi [2612 6993 1807]]

[Text] The key to realizing the four modernizations, quadrupling the annual gross value of industrial and agricultural output by the end of this century, and invigorating the economy lies in modernizing science and technology. The newly rising worldwide technological revolution precisely gives us an opportunity to use new technology to develop the economy.

First of all, it provides us with an opportunity to select and adopt the latest technological accomplishments. Over the past 30 years, the speed of the world's scientific and technological development has surpassed that of any other period and a number of new technologies have made their appearance. Of them, the newest accomplishments in the world's scientific and technological development are centrally seen in the following: information technology, biological technology, new-type materials technology, new energy technology, space technology, oceanological development technology, and so on and so forth. In certain fields and in regard to our strength in scientific research, experimental tactics, and results in scientific research, we have already acquired a certain degree and level of development. However, generally speaking, we are still rather backward in science and technology. Of course, it is necessary to pursue initial and opening up work in scientific research, but since there are already new technologies in the world, we can certainly select from among them and adopt for our use in accordance with our actual needs and possibilities. The advantages of so doing are that, in certain fields, it is possible to skip certain traditional development stages in technology but directly make use of relatively advanced results in science and technology. There is no need to start from the beginning. Savings of large amounts of manpower, material resources, and time may be achieved, comparatively large economic results may be attained, development of our economy may be speeded up, and we may narrow the gap between our country and the developed countries in the fields of economics and technology.

Second, it provides us with an opportunity to introduce suitable advanced technology to speed up technical transformation in our country. Driven by the new technological revolution, the developed countries are turning to

developing the newest industries and are willing to transfer certain traditional industrial techniques. To us, many of these techniques are still advanced techniques that are suitable for our use and that are relatively cheap in price. Under such conditions, we are in the advantageous position of spending less money but acquiring more techniques, thus accelerating the technical transformation of our original enterprises.

Third, it provides us with an opportunity to learn from the modernized operating and management methods of economically advanced countries. Driven by the new technological revolution, the operating and management methods of the developed countries have become increasingly modernized. For example, they use the scientific systems method and control theory to improve the management level and to strengthen statistical study, and supervision of economic activities and thus to facilitate economic development. Learning from these advanced methods is advantageous to gradually and fundamentally changing our management pattern from the type for the handicraft industry and to facilitate developing our productive forces and invigorating our economy.

Lastly, it provides us with an opportunity to speed up our scientific and cultural education and development of the intellect. With the extensive use of new information technologies such as television, microcomputers, and so forth it will be possible, under the conditions of a shortage of teaching personnel and the limited availability of funds, to greatly accelerate the popularization and improvement of science, culture, and education, to the end that the further development of the intellect of the people of our country may be achieved. This has far-reaching significance to our country's economic development.

In the utilization of the opportunities offered by the world technological revolution, we have acquired many experiences and lessons. In 1956, our party issued a mobilization call "to march toward the modernization of science" and formulated a 12-year plan for scientific development. The test explosion of the atomic and hydrogen bombs, the making of synthetic crystalline bovine insulin, and so on, have all testified to the correctness of our party's tactics of grasping the opportunity and greatly developing science and technology. Unfortunately, as a result afterward of the "leftist" trend of the guiding thought becoming increasingly serious and ultimately leading to the 10 years of disturbances, the already decreasing disparity between our country's level and the world's advanced level was once again increased. Indeed, opportunities should not be missed and the time will not come again. Now we should learn from this experience and lesson, make full use of the advantageous conditions before us, and step up our scientific and technological development.

Now that the world's new technological revolution has provided a good opportunity for our country's economic development and has issued to us a serious challenge, we indeed have a severe test before us.

First, it is a challenge to our relatively backward productive force. Over the past 35 years since the founding of the PRC, our productive force has

achieved rather great development. But, compared with the developed countries, a large gap still exists. We need some 50 to 70 years' efforts before we can catch up with the economic development level of the advanced countries. In the meantime, modern science and technology are developing rather rapidly and if we do not try hard to catch up we may fall even further behind. Hence, we should, on the one hand, emphasize the use of new technology to transform our traditional industries and, on the other hand, appropriately speed up the development of new scientific technology and build up new industries to the end that our national economy may as soon as possible be transformed to a new technological foundation.

Second, it is a challenge to our management system and traditional management thinking which do not quite fit in with the development of the productive force. Compared with traditional industries, the newly rising technology and newly rising industries possess the following special features: rapid changes in technology, rapid renovation of equipment, a high and stringent demand on the quality of the products, intensive market competition, and high risks in investment. On the other hand, our current economic management system, policy-making procedures, and management methods can hardly conform with these special features. Due to such faults and defects as the overcentralization of authority, lack of decisionmaking power on the part of the enterprises, and the practice in distribution of "everybody eating from the same big pot," together with other drawbacks such as demarcation and division between departments and localities, the inability to separate government from enterprise functions, lack of competition, and so on, it has not been possible to promote technological progress. Rather, the application and promotion of advanced science and technology have been impeded, resulting in a low labor productivity rate and poor economic results. Reform of these kinds of conditions is sorely needed.

Third, it is a challenge to our education, scientific, and research work. The new technological revolution calls for the formation of a generation of talented personnel adept at creating something new and capable of bringing about a new situation in whatever they do. It demands that scientific and technical personnel and managerial personnel must be adept at the use and handling of information and at inventing, creating, and modern managing, and must possess competitive abilities and adaptability. Although since the founding of the PRC we have scored many successes on the scientific and technological front and our educational institutions have trained a large contingent of persons of superior quality, yet due to the existence of many defects in the scientific and technological system and in the methods of management and of certain drawbacks in the educational system, our level of science and technology is still relatively low and the number of trained personnel is still very small, with some of them being low in caliber. This has brought along many difficulties to our modernization program. If we do not reform our structure of science and technology and our educational system, and do not speed up the development of science, technology, and education, then, the danger exists of our failing to achieve the targets of quadrupling the gross output value, invigorating the economy, and realizing the four modernizations.

Lenin said: "Communism precisely makes use of a labor productivity rate which is superior to that of capitalism and which is created by workers who are advanced in technology, who work conscientiously and of their own accord, and who are united." ("Selected Works of Lanin," Vol 4, p 16) The key to improving the labor productivity rate lies in the development and utilization of advanced scientific technology. Our socialist system possesses superior qualities with which capitalism can hardly compare and these superior qualities help in developing science and technology and improving the labor productivity rate. However, for various reasons, the superior quality of our socialist system has not been put to full play and has not fully displayed its enormous role of promoting the development of the productive force. If, acting on the basis of summing up historical experiences and lessons, we do not firmly rectify the defects of the concrete structure and its links, or make the socialist system even better, or enable our superstructure and production relations to conform, to a greater extent, with the demands of development of the productive force, then it will not be possible to make good use of advanced science and technology to greatly improve the labor productivity rate, nor will it be possible to basically solve the various social problems arising therefrom, nor to realize the goals of building a high degree of socialist material civilization and spiritual civilization.

CSO: 4004/7

MANAGEMENT OF S&T PROBLEM-SOLVING DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENTIOLOGY AND MANAGEMENT OF SCIENCE AND TECHNOLOGY] in Chinese No 6, 12 Jun 84 pp 27-30

[Article by Chen Xueren [7115 1331 0088] of the Tianjin Institute for the Study of Science, edited by Zhao Jian [6392 5329]: "The Significance of Coordinating the Solution of Key Problems and the Management of Problem-Solving"]

[Text] If one studies the history of scientific development, it becomes clear that scientific research is a form of labor, and that in its labor organization this research has taken the path of passing from individual efforts to that of the group and from the samll group to the large. If we look at the period before the middle of the 19th Century, we see that the dominant form of scientific research activity was that of a scientist working as an individual, and that by the 1870's, with the establishment of Maxwell's Cavendish Laboratory in England, Edison's Menlo Park Laboratory in the United States, and the Bell Telephone Laboratories in the United States, the era of the scientific researcher laboring as an individual had concluded. By the 1930's, along with its rapid development, science and technology underwent some important internal divisions. Many new disciplines were established, the division of labor in scientific work became increasingly specialized, and the problems confronting scientific research institutions increased in complexity. The instrumentation and equipment required to do scientific research grew larger daily. At the same time, still greater expenditures were required in manpower and materials. For these reasons, there is an urgent need for a new research model to replace the collective research model, suited to the contemporary developmental needs of science, technology and society. This new model is called "coordination" in English. In China, however, in inter-disciplinary, inter-departmental, trans-regional and even trans-national research, we have habitually used the term "coordination" to refer to coordinating projects (i.e., overcoming technical difficulties) and call it "coordinated problem-solving."

Selection of key problems to be solved.

I. Basis for selection.

When addressing key problems to be solved, the basic principle for selection is fundamentally one of suitability, but because these problems are all part of high-priority projects, their expenditures in people, funds and materials, as well as their degree of difficulty, are relatively large. Therefore, we need to emphasize the following several points:

1. Strategically important S&T problems which urgently require solution are weak links in our national economy and the buildup of our national defense; solution of these key problems hopefully will bring economic and societal benefits or S&T breakthroughs.

2. Focus on the difficult S&T problems posed by national economic development planning and the national emphasis on construction and technological transformation.

3. In the early stages of research, focus on the research feasibility of construction problems.

4. Major imported projects should be digested, assimilated and transformed, until they are ultimately shaped into our own technology.

5. Pay attention to societal problems urgently awaiting solution, e.t., medicine and health maintenance, family planning, environmental protection, ecological balance, cultural and physical education, etc.

6. Promote the coordinated development of science, society and the economy in the important class of topics called "soft sciences."

II. Procedures for selection.

1. Justification for tackling a key problem.

The major substance of the justification is as follows:

(1) Let technological policy be the guide. Technological policy indicates what technological approach a profession (or industry) should take within a certain period of time. Initially there should be an examination of the technical level the project is to attain. Because of the concern with schedules, some projects require a short time to show results, while others will take longer. There should be a study as to what technology should be recommended, limited or eliminated. There should also be a study as to whether domestic or imported technology should be employed in the solution.

(2) Make a technical and economic analysis. There must be a quantitative explanation of whether the project is technologically advanced, and whether it is economically feasible or realistic. There is also the need to consult developmental trends abroad, carrying out the project with developmental vision: some long-range, directional topics cannot produce results for a time, still arrangements should be made for them.

(3) When tackling major problems which are linked with basic construction or technological transformation, there should be a definite emphasis on forming them into a productive force, in order to advance the development of the national economy.

(4) In order to avoid the phenomenon whereby the contents of research separate from one another, there should definitely be compatibility. Some research results simply cannot be converted directly into a productive force. Besides policy and organizational reasons, other important causes of this are gaps and incompatibility.

2. Determining problems to be solved.

After justification of the project, a few more things need be done, for there can be no final determination of the problem-solving mission and objectives until they are clarified:

(1) Look into the resources situation. Do research on superior technical ways of effectively bringing resources into full play. In the broad sense, technology is also a resource, namely the intellectual resources of people. Superior natural resources are but a kind of potential superiority, and only by joining them with superior technical talent can natural resources be processed into some depth of development.

(2) Understand the technical level. Determine which of our items are technologically superior and then seek effective ways of bringing these into full play.

(3) Find out the state of the art, both domestically and foreign. Through various information channels and forecasts, there should be as deep as possible a comprehension of the current technological situation and developmental trends both here and abroad, so that we can determine our objectives and seek out those things we can learn from.

The management of problem solving.

I. The work of managing problem solving should adhere to principles.

1. Gear to the needs of the economy. In order to suit the needs of national socialist modernization construction, when in the technical line of problem solving, implementing a program and carrying out its technical and economic justification and evaluation, it is essential to adhere to a plan which gears science and technology to the needs of the economy. First of all, examine the objective needs of state and society for S&T development to advance the national economy and build the national defense, as well as examining the development of S&T itself.

2. Mutual assistance for mutual benefit. Mutual assistance for mutual benefit is the foundation of coordination. Every coordinating unit should develop fully every objective to a position of superiority in its discipline, overcoming shortcomings by learning from the strong points of others. These mutual benefits will create high level technical results in the fastest possible time, will toughen our ranks, and raise their level.

3. View concepts as a whole. Modern S&T research is not only a kind of creative activity, it is also an economic activity. At the same time we look at technological advancement and economic rationality, we must also be sure that

we reach advanced technological norms. We also want to obtain as fast as possible relatively good economic benefits and positive societal results. For this reason, when determining the various research topics involved in solving key problems, in addition to implementing the project plan and justifying its technical procedures, etc., we must also seriously implement research expense budgets and make a forecast of the economic benefits and societal influences. In the whole research process, there should be a conscientious gathering and sorting of research and economic data, in order to assure reaching the anticipated goals.

4. Concentrate on unity. Management work has both the characteristics of authority and the characteristics of organization. In organized management work, many disciplines and units participate in coordinated problem solving. An organization which assumes organizational management work, if it is to accomplish a given assignment, must have a clear understanding of what its responsibility is, and at the same time it must be given whatever authority it requires to accomplish this assignment. Moreover, on the basis of complete respect for science and the viewpoints of all participating units, the organization assuming responsibility for organizational management work should insist on a concentrated unified leadership. For it is only in this way will they be able to coordinate and unite every research unit participating in the problem solving, putting an all-out effort into the research work.

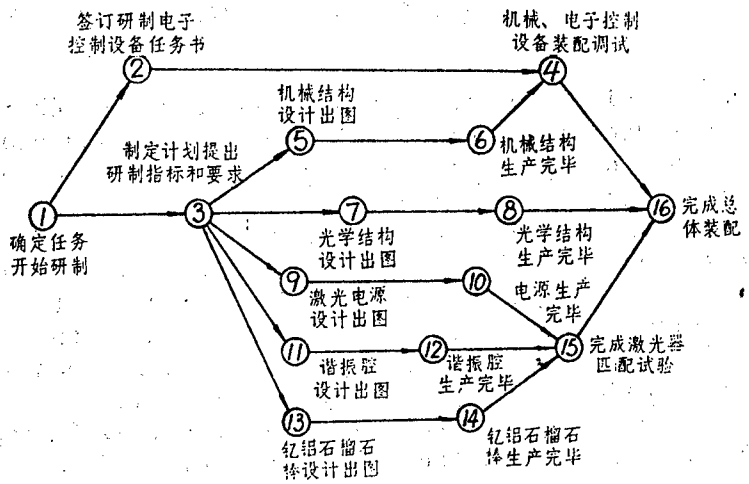
II. Methods and procedures for management of problem solving.

The nucleus of problem solving in organizational work is in formulating a plan for problem solving and organizing its implementation. There are many methods for managing problem solving. One type that is widely employed abroad is the project coordination technique.

In 1958, when the United States developed the Polaris guided missle submarine, a new scientific methods of project management was employed for the first time; this was the project coordination technique. In the United States this kind of technique is called "PERT." It was begun in China in 1962 with the proposal and support of Comrade Qian Xuesen [6929 1331 2772]. In 1963 this new project management technique was used in the work of developing an electronic computer, and obtained obvious results.

The planned coordination technique is one that is often used in systems engineering. It takes the various tasks that are components of the mission objective, and forms these components into a unified project flow chart according to their technical and organizational interactions. After that, mathematical methods are used for analyzing, forecasting, distinguishing primary from seconcary, clarifying what is critical, and seeking the best plan for using resources. Moreover, the process of drawing up and implementing the project is at the same time a type of organizational management technique for carrying out revisions.

To illustrate the principle, we will now take the development of a numerically controlled laser drill as an example, and draw up an extremely simplified flow chart. (See illustration).



Project Flow Chart

1 Define mission and initiate preparations.
2 Conclude and sign mission documents on preparing electronic control equipment.
3 Formulate plan setting out development goals and requirements.
4 Install and debug mechanical and electronic equipment.
5 Produce drawings for construction of mechanical equipment.
6 Complete production of mechanical construction.
7 Produce drawings for construction of optical equipment.
8 Complete production of optical construction.
9 Produce drawings for laser power source equipment.
10 Complete power source production.
11 Produce drawings of resonant cavity equipment.
12 Complete production of resonant cavity.
13 Produce drawings of yttrium-aluminum-garnet (yag) laser equipment.
14 Complete yag laser production.
15 Complete testing of laser instrument matching.
16 Complete overall assembly.

Actually, the items in a flow chart will number in the hundreds and even the thousands, and so are much larger than this, as much as several meters in length.

The flow chart is put together by comrades familiar with the total plan and with technological coordination, and is done after they have assimilated all ideas on the various aspects of the project. The chart can reflect fairly completely everyone's understanding of the objective laws of the time, and as much as possible the maximum effort that can be attained. It reflects how systematic, coordinated and compatible are the entire mission's contents, and also reflects the plan of the total mission. The chart, then, is a basis for our planning work.

Although the planned coordination technique is not extremely complex, still it does have a lot of content. As space is limited, we can only recommend the method here, and not provide a complete introduction to it. Detailed discussion can be found in books on the subject.

The management of problem solving calls for a systematic outlook which grasps all links in the chain, and carries out effective regulated control, in order to attain the anticipated goals. In general, the process of managing problem solving consists of the following:

1. Determine the project's responsible experts and the project's management unit. This is a prerequisite for accomplishing problem solving. The project's responsible experts, besides being knowledgeable about the project and matters related to it, must also have a profound understanding of the project's political and economic significance, as well as the party's general and specific policies. They will also be familiar with conditions in concerned departments, and will be people these departments know they can trust. At the same time they will have definite organizational capabilities, capable of developing an academic democracy and arousing the enthusiasm of the S&T personnel participating in the project.

The people in charge of the organization responsible for managing the project's coordination should be capable of working closely with the responsible experts. They will keep the cardinal principles in mind while taking the overall situation into account. They will be people of action adept at taking command and planning strategy. This organization will have flexibility in its professional work and its support system, and can make use of these for organizational coordination anywhere in the entire project. Operating in this way gives the project strong expert leadership, while also providing an authoritative command system.

2. Determine the problems at every step in the project, while carrying out an overall program justification. The projects responsible experts, in accordance with the needs of the unit transmitting the project and other concerned units, will propose each step of the project and clarify the status and significance each has for the project, as well as their relationships to each other. They will propose the first draft of the overall plan. The unit assigning the project will convene discussion meetings, and carry out an appraisal by persons in similar professions.

3. Determine the unit that will carry out each stage of the project and carry out program justification. After the overall plan is adopted, as an outgrowth of the topical planning and discussion meeting convened by the project's responsible experts and the managing unit, there will be a comparative examination

of the plan's state of technological advancement and feasibility, to determine whether the research period is appropriate to the total mission requirements, whether the level of technology put into the project is high enough, are the forecasted economic benefits high enough, etc. This will be done in order to invite bids or find other ways of soliciting the units responsible for each stage of the project.

4. Conclude an agreement for the research contract. Contracts for coordinated problem solving can be divided into two categories:

(1) The mission (or vertical) contract: after the overall plan is set, a coordination and research document will be concluded between, on the one hand, the managing unit along with the project's responsible experts (the party of the first part), and on the other hand the unit assigning the project (the party of the second part). It will clearly stipulate such things as technological requirements, target schedule, calculated expenses, mission time limitations and disposition of results, responsibilities and obligations assumed by each party, etc., setting out norms both sides will adhere to in common.

(2) The acceptance (or horizontal) contract: this is concluded between two units which are at the same, or at two related, levels. It will stipulate what technological and economic targets must be attained by the first level (or unit) before acceptance by the next level (or unit).

5. Draw up a project flow chart. Refer to the previously related planned coordination technique flow chart for drawing methods.

6. Implement monitoring as part of the project process. In order to achieve the general goals of the project within time limitations, it is necessary to monitor the course of the project, step up feedback, timely discovery of problems and solution of problems. The monitoring should consist of:

(1) Monitor the plan's schedule. A planned schedule for problem solving should differ from a plant's production schedule. It should certainly be flexible, and decisions should be made on the basis of scientific research. Therefore, to specify that by such and such a month and year the project should be up to a certain level is both unrealistic and unscientific. However, a level's scheduled plan must be set out and should be monitored.

(2) Monitor the expenditure situation. Funds expended on the project should be "earmarked funds," putting an end to extravagance and avoiding the practice of spending money just because there is enough of it or spending so freely at the start that there is too little later on. This can result in research work being interrupted or even terminated prematurely.

(3) Monitor the personnel deployment situation. When a level is put into practice, if it is found that the division of labor at an early period is not the most appropriate, then prompt adjustments are called for.

(4) Monitor the instrumentation and equipment situation. When a level is put into practice, it still might be found that the use of some valuable and unusual equipment is inappropriate for the situation. In such cases, there should be an immediate adjustment, with other equipment brought into use. It is best to have a valuable allotment, as they will be decreased by accidents.

(5) Monitor the thought situation. When a level of coordination is put into practice, it is understandable that this or that kind of ideological question will emerge. If there is an ideological question or occurrence which threatens unity, it should be solved promptly. If a real solution is elusive, there should be an investigation into possibly taking the steps to carry out transfer of personnel (or units), in order to avoid the "internal cost" being too great and adversely affecting the time schedule.

7. Results at each level and the acceptance check of results. In the coordination of joint multi-disciplinary problem solving, it often turns out that in a particular project there will be several individual topics and a still larger number of subordinate topics, and it will not be possible to obtain results in all these topics simultaneously. First to last, it is inevitable that they will appear dissimilar upon examination, with the consequence that the check on acceptance for results at each stage cannot be imposed uniformly. The project's experts in charge are responsible for the project's final results and for the stage results; persons responsible for the topic at each level are responsible for the results of the topic at each level and for the results of that stage of the project. In order to meet the needs of the unit which proposed the mission, the unit responsible for each level's topic will promptly pass on the results at their level to the next unit.

8. Project cancellation. The responsible persons in charge of a project and responsible experts must also have the foresight and courage to cancel a research project promptly. Some projects, although they were not poorly selected, still once they are underway a careful analysis will ascertain that it is senseless to go ahead with them. This can be due to a changed situation or technical problems. In these instances, a firm decision must be made and the originally scheduled plan terminated, even though there may have already been a considerable expenditure in manpower and materials. Any indecision or stalling for time may possibly lead to even greater losses. There may be a definite procedure for project cancellation. In order to be cautious, it is best to carry it out according to the project's set procedure, with all responsible units equally powerless to unilaterally cancel a project.

9. The project summary. Summarizing the project is the final step in the process of coordinated problem-solving. In sumarizing the project, the essentials of the research objectives can be brought out, legal questions can be sought, as guides to practical application. The summary in its final form will be technical material, such as a research paper or report, or a design drawing.

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12625
CSO: 4008/358

STANDARDS FOR EVALUATING S&T RESULTS

Tianjin KEXUEXUE YU KEXUE GUANLI [SCIENTIOLOGY AND MANAGEMENT OF SCIENCE] in Chinese No 6, 12 Jun 84 pp 31-34

[Article by Luan Zaochun [2940 2483 2540] of the Heilongjiang Academy of Social Sciences, edited by Zhao Jian [6392 5329]: "On Standards for S&T Results and Their Appraisal and Verification"]

[Text] The work of managing S&T results holds an important position in the overall work of S&T. Because S&T are so useful in socialist economic construction, it is primarily through the exchange and dissemination of their results that this construction is achieved. Finding and judging S&T talent is also largely attained through the appraisal and verification of S&T results. For these reasons, defining and appraising S&T standards of achievement are always important theoretical and practical problems of S&T management work, deserving of thorough discussion.

1. Definition and standards of S&T achievements.

What are S&T achievements? What are the specific standards for them? This is the first question to be answered.

Concerning S&T appraisal, on 7 April 1963 the State Scientific and Technological Commission (SSTC) handed down "Regulations Concerning the Reporting and Registry of Scientific and Technical Research Achievements (Trial Draft)," which made the following general statement: "The term research achievements refers to those S&T research projects which, having undergone experimental research, investigation and consideration, are concluded to have definite scholarly or practical significance." This is a pretty general definition, and does not set out a clear standard for achievements. Later, the SSTC's Achievements Registry Office supplemented this by saying, "Any basic unit's S&T research achievements which have not been submitted in a written report, or which have been reported but not yet investigated and verified, will not be passed on to higher authority as achievements." This supplementary explanation, then, stipulates that S&T achievements must be investigated and verified.

The regulations were revised in 1963, and then on 13 November 1978 the SSTC promulgated "On Management Methods in S&T Research Achievements," which gave a new regulation for the definition and classification of S&T achievements:

"These methods separate S&T research achievements into three categories: (1) Research achievement, that is, theoretical research achievements which show creativity in some aspect of the natural sciences. (2) Technological achievement, that is, a new technology, method, product or craft which either increases production or makes it faster, better or more economical. (3) Preliminary results which are of importance to S&T achievements."

This new regulation was clearer in some aspects than the 1963 regulations, and if achievements are put in the three categories, most fall into category (3). But they are still fairly general, with no clear standards, and no emphasis on the need for S&T achievements to undergo appraisal and verification. The third category is somewhat inappropriate: incomplete work cannot be defined as an important achievement. It would seem better to say: "Preliminary results important to S&T research projects." If these preliminary results are of an independent and complete nature, then they can in practice be applied on their own.

We recognize that the following points should be clear in defining S&T achievements:

(1) S&T achievements are the results obtained when a research topic is completed;
(2) the kind of S&T achievement;
(3) the significance and maturity of S&T achievements must be appraised and verified.

We know that S&T achievements come from every type of research (basic, applied, developmental), every type of research topic (including preliminary research topics of importance to long-range S&T research programs), and that results from successful completion and have gone through appraisal and verification which affirmed them as being scholarly significant theoretical achievements or technological achievements which have practical significance for production. Theoretical achievements may include any of the following:

(1) Scientific discoveries (new laws, characteristics, phenomena, etc.);
(2) Theoretical explanations of familiar phenomena (giving a systematic analysis of laws, principles, hypotheses, models of observational data, etc.);
(3) New proofs of controversial scholarly topics;
(4) Demonstrations of scientific principles underlying existing technology;
(5) New creative scientific research methods and experimental methods;
(6) Systematic scientific research materials (illustrations of flora and fauna, collections of specimens, geologic map collections, etc.);
(7) Syntheses of scientific research reports, etc.

Technological achievements may include any of the following:

(1) Technological inventions:
(2) New technology of a definitely advanced technical level, which has been tried out and has potential for wider use;
(3) New crafts, methods, etc., which are of a definitely advanced level, have been tried out, and have the potential for wider use;
(4) New products, equipment, materials, etc., which are of a definitely advanced level, have been tried out and have the potential for wider use;

(5) New standards or designs which are of a definitely advanced level, have been tried out and have the potential for wider use;
(6) New products having economically beneficial effects, or having within a distinct sphere the potential for wider use in agriculture or animal husbandry.

Technological achievements should at the same time meet the following three criteria:

(1) Be technologically advanced: they should be of a definitely advanced level (this refers to the international, national, regional or unit's level of advancement).
(2) Be economically reasonable: they should be economically reasonable and should produce some amount of economic benefits.
(3) Be practical for production: they should be something which it is practical to produce, have universal significance, and moreover have been proven through trial practice to have the potential for wider use.

In the past, standards for technological achievement were not sufficiently defined, and a significant portion of research results were put into production without having been tested in practice. Or, despite having only partially significant technological innovation or minor reforms, still were regarded as technological achievements.

What is meant here by a scientific discovery is something which was not known before, a phenomenon which exists in the objective world, special properties and laws concerning phenomena and theoretical explanations of these. These are discoveries and theories which engender important changes in mankind's level of knowledge and in those theories already known. Some examples of this would be the phenomenon of superconductivity, the characteristics of light, the discovery of the theory of relativity and discussions of it, etc. Phenomena are the revealed natures of objective things. The discovery of new phenomena, then, can take us a step further in unmasking the nature of things. Characteristics are those ways in which certain things differ in their essential nature from other things. For example, that visible light is a type of electromagnetic wave at a particular wave length and frequency range, and that it differs in this regard from invisible light. Laws are those essential relationships which are repeated within a class of phenomena. These essential relationships can use theories to express and define their natures and quantitative relationships. For example, Einstein's theory of relativity described the relationship between the motion of matter, time and space.

Scientific phenomena should at the same time possess the following three criteria:

(1) Absolute originality: it must be something that was previously unknown anywhere in the world.
(2) Objectivity: it is something which exists in the objective world, and not a subjective creation.
(3) Modifying: it engenders important changes in mankind's level of knowledge and theories.

Let us continue with our discussion of standards for technological inventions. The "Regulations Regarding Awards for Inventions in the Peoples Republic of China" makes this stipulation regarding technological inventions: "In these regulations the term 'technological invention' means an important new achievement in S&T, which at the same time meets the following three conditions: (1) it was previously unknown; (2) it is advanced; (3) it has practical application."

We realize that technological inventions are the highest level of technological results, and should be required to be higher than the level of technological results in general. But the "Regulations" are rather vague concerning technological achievements, and do not specify their level of advancement nor do they indicate clearly that technological inventions are a type of technological result. Therefore it is necessary to move further in clarifying requirements and standards for technological inventions.

Based on the three standards for technological achievements that we mentioned earlier and the three stipulations listed in the Regulations, we see that technological inventions should at the same time meet the following three standards:

(1) Absolute originality: it must be something previously unknown anywhere in the world.

(2) Advancement: it must be a creation which is at the international or national level of advancement.

(3) Practicality: it must be a kind of technological result which can, through documented experience, be put into widespread application (new technology, new products, new equipment, new materials, new crafts, etc.).

It is obvious from the above three standards that the requirements for technological inventions is rather high. We should not lower the standards for them, but should seek better technological results to consider as technological inventions.

But scientific discoveries and technological inventions are two completely different types of S&T achievements. There should be different requirements and standards for each, and it is important to pay attention to not getting their differences confused.

2. Appraisal of theoretical achievements.

Dissimilar kinds of S&T achievements have dissimilar standards and methods of evaluating them. In general, theoretical results are evaluated through discussion, while technological results are evaluated through verification. At present, China does not have uniform regulations for standards and methods of evaluating theoretical results. China only has promulgated the "Regulations on Natural Science Awards," which stipulate that "Any collective or individual research achievements which clarify scientific phenomena, characteristics or laws, and which have important significance in S&T development, are eligible to receive natural science awards." This regulation is also merely a statement of principle on standards for theoretical achievements, and its standard of having "important significance in the development of S&T" requires further clarification.

We have previously discussed standards for scientific discoveries, but have not yet determined standards for theoretical results. If we refer to the "Regulations on Natural Science Awards," and the three standards for scientific phenomena which was discussed earlier, we see that there are mainly two standards for theoretical results:

(1) Be of a scholarly level

The chief standard by which theoretical results are evaluated is that they should be at a scholarly level. That which we call scholarly is a measure of comparison, indicating what degree of advancement the theoretical results have attained in the world.

We realize that the theoretical results which have the highest level of scholarship should be scientific discoveries, because they will hold an absolutely leading position in the international level of advancement, and are things which were previously unknown to mankind.

For theoretical results other than scientific discoveries, the standards can be divided into two types: results which are at the international level of advancement and results which are at the national level of advancement. Because the results of theoretical research are virtually always of universal significance, there are none which are only regional in nature, so we do not refer to results as being at a regional level of advancement.

Results which are at the international level of advancement are those which hold a leading position when compared to others throughout the world. Speaking in general, theoretical results should all be at the world's level of advancement, because they resolve a problem of the "unknown." If the results which you obtain are in problems already solved by others before you, or if the conclusions you reach lack any new significance, or are not original ideas, and do not surpass in depth or breadth the currently existing level, then we are not talking about any world level of advancement. Why then do we propose a national standard for level of advancement? This derives from examining the differences that exist among nations in the degree attained in science and technology. If we just look at the situation in an individual country, and the theoretical results in question are those which were previously unknown in that country, or are in the ranks of the advanced within that country, then they should be recognized as being at the national level of advancement.

(2) Be scientifically significant

Theoretical results generally all have scientific significance, useful in enhancing the development of scientific theory and mankind's cognitive ability. But their practical significance, that is, their use in the development of technology or the economy, often cannot be seen for awhile, and often gradually become evident only with the passage of time. For this reason, when reviewing theoretical results, the emphasis should be on looking at their scientific significance.

The standards for judging the scientific significance of theoretical results should in the main be viewing their significance as a general guide in the development of science, in the depth and breadth of their influence. Discussed in this context, we see that scientific discoveries are of the highest standard, since they are absolutely original, and can engender major revisions in mankind's level of understanding and in theories already known. It is possible that some scientific discoveries have a scientific significance that is still as yet unclear, with a scope and depth of influence which cannot yet be known; in these cases, it may be best to not make an immediate assessment, but often better to wait awhile before doing so. In judging the scientific significance of other theoretical results, the emphasis should be on how great is the depth and breadth of their influence in the development of science.

Because the level of scholarship and scientific significance of theoretical results are not things which can be seen clearly at first glance, the method of evaluating theoretical results should be to emphasize selecting both the delayed and the peer methods of evaluation. At least 1 year should elapse after publication of the theoretical results before convening a peer evaluation meeting. There is a sizable literature already on peer evaluation meetings, so we will not go into them further here, except to draw attention to one point, namely that the scope of the peers should not be too narrow. Because contemporary science often sees various sciences infiltrating one another, taking on the characteristics of joint development, the selection of "peers" who participate in the evaluation meeting should be in the broad sense, with invitations to scholars from peripheral as well as the same disciplines to take part in the meeting. If we look at what is needed in management work, we see that China should immediately formulate rules or regulations which deal specifically with the evaluation of theoretical results, defining the standards and methods of evaluation, evaluation procedures and qualifications for evaluating personnel, plus documents concerning conclusions of the evaluation, etc.

3. Appraisal of technological results.

Appraisal of technological results should be by the verification method, and for this China has clear-cut regulations. On 13 November 1978 the SSTC handed down the notice "On Management Methods in S&T Research Achievements," which directed: "S&T research results must go through rigorous verification, and with the verification methods conducted according to the 'Provisional Methods for Verification of New Products, Crafts and Technology' published by the State Council on 22 April 1961." The "Provisional Methods" are only a statement of principle, so it is necessary again to go further in clarification. We will propose only a few points for discussion here.

1. On standards for verification.

Norms and standards for appraisal of technological achievements should conform to the aforementioned three standards of technological achievements, with an emphasis on studying how advanced they are technologically, how realistic they are economically, and how feasible they are for production.

What constitutes technological advancement can be differentiated as follows: (1) the international level of advancement; (2) the national level of advancement; (3) the regional or departmental level of advancement. Economic realism can be differentiated as follows: (1) economically realistic and having obvious economic benefits; (2) economically realistic and having relatively good economic benefits; (3) only relatively realistic economically but with definite economic benefits; (4) economically unrealistic. Production feasibility can be differentiated as follows: (1) technologically mature, can be put into production, and can be widely expanded; (2) technologically mature, can be put into production, and be expanded for use within a limited sphere; (3) technologically immature, with its production design not yet finalized, still needing to be perfected; (4) technologically immature, with no potential for going into production.

In the above three standards it is the third which requires the closest attention. In the past there have been a fair number of what were called S&T results which were technologically advanced and economically realistic, but because they were insufficiently mature from a technological standpoint, lacked feasibility for putting into production and could not be directly selected by production departments or put into application in a wider sphere. For this reason, the third standard must be managed well, and research results which are immature technologically, unfeasible for production, have only gone through laboratory testing, absolutely cannot be put into production or applied to wider use. S&T results must be verified, otherwise we can produce a batch of "gifts, charms and exhibits."

2. On the attitude with which we approach verification.

Verification of results is the complete examination of research work, the complete check of S&T results. It can be a test and review of the planning and organization of research work, of the results of the labors of research personnel and of their professional level, of research expenditures and of the rational use of equipment and materials. It must be an accurate verification of the degree of technological advancement of research results, of their economic realism and feasibility for production; it is directly related to the present and future development of management of all types of S&T and the fate of S&T results. Thus, the work of verifying S&T results is work of the utmost significance, and must be approached with the utmost seriousness.

Verification committees and verification personnel must definitely be in conformance with national mission and research personnel's spirit of responsibility. Their attitude toward verification work must not be matter-of-fact, but rather conscientious about every detail. They must not give undue praise to major S&T achievements, and not belittle the worth and usefulness of minor S&T achievements. They must guard against going through the motions, and must not let the evaluation meeting turn into a "victory banquet."

12625
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APPLYING LEGAL SYSTEM TO S&T MANAGEMENT DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENTIOLOGY AND MANAGEMENT OF SCIENCE AND TECHNOLOGY] in Chinese No 6, 12 Jun 84 pp 36-37

[Article by Wang He [3769 3109], Guangzhou Jinan University; edited by Chu Xiao [0443 2556]: "Certain Problems in Applying the Legal System to the Management of S&T "]

[Text] What is the S&T legal system?.

What we refer to as the S&T legal system is a generic name for the laws and standards which are concerned with S&T. It takes the legally effective on S&T policy, applies laws and regulations in the management of S&T, and uses legal means to encourage and protect innovations in S&T disciplines. It includes the legal system which protects and rewards innovations, the legal system which safeguards and utilizes innovations, the patent legal system, the trade mark legal system, the S&T legal management system, etc.

The legal regulation of S&T has a lengthy history. In China there was a unified set of product standard laws. In the 13th and 14th centuries, the English kings sought economic prosperity by issuing decrees which gave merchants exclusive rights to manufacture certain products. In 1474, at the heighth of trade between East and West, the economically well-developed Venetian Republic issued a decree protecting patent rights on inventions. Accordingly in 1594, the famous scientist Galileo was awarded a 20-year patent for his invention of the irrigation pump.

The legal regulation of science and technology as we know it today began to be shaped and developed along with the progress of capitalist economic development. By the 17th and 18th centuries, such nations as the United States, France, the Netherlands, Germany and Japan had made the formulation of patent laws a priority item. Particularly since the 1970's, along with the rapid development of science and technology and exacerbated by the competition for raw materials and markets, and the growing intensity of technological monopoly and patent competition, we have seen the continuous development and daily filling out of S&T legal regulation. This has now entered a new phase. One after another, the developed capitalist nations, adapting to new requirements, have modified their patent laws. Now, some Third World nations are formulating their own laws and regulations in order to free themselves from the technological monopoly and economic domination of the superpowers and developed capitalist nations, and to protect their inventions and technological progress.

At present, the legal regulation of science and technology is becoming daily more international. In 1970, based on the World Convention on Intellectual Property Rights, the World Intellectual Property Rights Organization was established. In Washington, 35 nations concluded a Treaty on Patent Cooperation. In 1973 the European Patent Treaty was concluded in Munich, West Germany, establishing the European Patent Office. At the end of 1975 the European Community Patent Convention was concluded in Luxembourg, with all rights of the Community member nations in regards to patent award, transfer, revocation and expiration being regulated by this treaty. In actuality, this is a unified patent law for the Community member states.

Why should science and technology be regulated by legal methods?

The relationship between science and technology can be summarized as follows: The legal system has developed right along with the continual progress of science and technology, and the management of science and technology cannot be separated from the legal system. Management of the S&T legal system can also guarantee and promote the development of science and technology.

Science and technology is a powerful motivating force in the development of the national economy. Its condition directly affects the nation's future and the destiny of our people. The modernization of science and technology occupies a key place in the four modernizations. At present, China's science and technology is about 20 to 30 years behind that of the advanced nations, the management level about 40 to 50 years behind, and our management thinking farther back still. Some specific research units look upon this situation as if the government had approved a patriarchal system, whereby one person's word was law. In their work they implement the simple administrative methods of old, managing science by unscientific methods. In organization, they are devoted to what they have done all their lives, ranking people by age and status, wasting talented people or stifling their talents. In their research system, they seek the "large and complete," or "small and complete." In work style they erect ideological blockades. It goes on and on like this. If we are to alter this situation, it is essential that we firmly and unflinchingly implement the legal system in science and technology and hasten the passage of S&T legislation, in order to meet the pressing needs of scientific and technological modernization.

(1) Strengthening the S&T legal system is a requirement if we are to have scientific democracy and reform of S&T management. The completed legal system which passed the S&T legislation setting up research units also established the research institutes' power to act independently, thereby making their principle rights real as well as nominal. The application of legal methods in the coordination of the various kinds of legal relationships between higher and lower levels, and between various systems, is the putting into writing of the research missions, organizational principles and work procedures of each. This will reform that sort of situation whereby those without regulations can proceed as they wish, but those with regulations cannot. It will strengthen the system of democratic and scientific legal management of science and technology, thereby constantly raising the level of S&T management.

(2) Strengthening the S&T legal system is a requirement for vigorously developing out S&T talent. As the laws concerning talent grow to maturity, various rules will be formulated which implement such systems as hiring, examination, promotion, degree of responsibility and rewards, using legal forms to affirm the legal position of S&T personnel, setting out clearly their rights and obligations. These should expressly stipulate that to waste or stifle talent, or to interfere with artistic freedom, are unlawful activities, and to persecute talent is a criminal activity. If it were like this, talented people would maximize their talents, with each in his proper niche. Using legal methods to assure bringing talent to maturity will rapidly change the situations of temporary shortages or a lack of people to carry on.

(3) Strengthening the S&T legal system will serve to advance scholarly exchanges. Currently, within China the technologically blocked off zone is universal, and many technological achievements cannot be exchanged promptly, with no way of disseminating them. In international cooperative exchange, due to inaccessibility and an imperfect system, there are many failures and some of our accomplishments have been taken and their patents applied for by foreigners. Also, there are some foreign ideas which cannot be marketed here. For these reasons, we need legislation on the protection, technological transfer and patenting of our accomplishments which will apply the legal system to the advancement of scholarly exchange both here and abroad, ensuring that S&T achievements will promptly be put to use in the service of society.

(4) Strengthening the S&T legal system will change science and technology quickly into an immediate productive force, assuring the realization of economic benefits. The development of S&T is not in itself the objective, but rather the unceasing promotion of productive forces, and the vigorous development of our fundamental national objective of high economic benefits and development. However, for many years now, owing to the erroneous influence of leftist guiding ideology, we have rejected experts and paid no attention to science and technology. In addition, in our S&T development we have given our full attention to only the most refined and highest S&T, disregarding totally the development of that technology which has the widest potential use, in a blind attempt to catch up with and overtake the more developed nations. In order to change this inappropriate situation quickly, we must strengthen our economic and legal system, by using legal means to ensure that the economy's and society's vital policy making development has a foundation in scientific research and abundant technological demonstration. We must progressively raise that proportion of the national budget which is expended on research, and link the rational reorganization of the macroeconomic structure with the technological transformation of our older industries. Use our limited technological strength where it is most needed; moreover, apply legalized economic methods to the management of science and technology to promote the close integration of S&T development into the development of the national economy. This will ensure the realization of a highly developed national economy.

What is the award system in natural science?

That which we call the reward system in natural science is itself a legal system, one designed to protect and reward scientific discoveries. It has its source in the Chinese Academy of Science's bonus system. In 1979, the State

Council promulgated the "Regulations Regarding Bonuses for Scientific Discoveries in the PRC," which converted the science bonus system into a natural science award system. The heart of this system is its protection and encouragement of scientific discoveries in the natural sciences. "Natural science awards may be given to anyone, collective or individual, whose research results serve to clarify natural science phenomena, characteristics or laws, and which have major significance for the development of science and technology."

To determine who gets an award, China has chosen a four step sequence, consisting of recommendation, trial, assessment and approval. Every research organization, academic institution, national learned society or more than 10 scientific workers above the rank of research fellow or equivalent acting as a group, may make recommendations on scientific research accomplishments to be rewarded. Recommended topics are evaluated separately by units of the CAS, the Ministry of Education, the China Scientific and Technical Association, the State Agricultural Commission, the State Economic Commission, the Ministry of Public Health and the National Defense S&T Commission, then are turned over to testing organizations. The topics to be tested are put through identical deliberations, including public appraisal, and recommendations are then made as to the level of the award. The State Scientific and Technological Commission has established a Natural Sciences Awards Committee, which is responsible for assessing the topics to be awarded and the amount of the award. The final step is ratification by the State Scientific and Technological Commission.

After ratification of the awards, they are given immediately to the individuals or bodies by the State Scientific and Technological Commission. Awards consist of a certificate of honor, a medal and a cash bonus. A first class award is 20,000 yuan, second class is 10,000 yuan, third class 5,000 yuan, and fourth class 2,000 yuan. This is the nation's legal acknowledgement and protection of the award winner's priority rights to his discovery, and anyone who is not infringing on others or submitting the same scientific discovery a second time may in this way pursue acknowledgement of his discovery rights. If the award is a collective prize, then it should be distributed in proportion to the size of the contribution made by each researcher participating on the award-winning project. Scientific research achievements which are of particularly major significance for clarifying natural phenomena, characteristics or laws can, with State Council approval, receive a special natural science prize. In order to encourage Chinese nationals residing abroad and foreigners to make contributions to the development of China's science and technology, those in this category who are engaged in natural science research and have obtained excellent results, are also eligible for awards. In order to ensure that this legal system of natural science awards is carried out in practice, the "Regulations Regarding Bonuses for Scientific Discoveries" expressly provides that, "Nominations for awards should be practical and realistic, and must receive serious consideration. In cases of fraud or deception, those who are a party to these must be dealt with severely, in accordance with the degree of seriousness of the plot."

12625
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SOME PROBLEMS IN PATENT LAW IMPLEMENTATION EXAMINED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENTIOLOGY AND MANAGEMENT OF SCIENCE AND TECHNOLOGY] in Chinese No 6, 12 Jun 84 pp 38-39

[Article by Dong Jin [5516 6651] and Yuan Suohong [5913 6956 7703] of the Shanghai Institute for the Study of Science, edited by Huo Hua [3499 5478]: "Some Problems in Patent Law Implementation"]

[Text] The formulation and implementation of a characteristically Chinese socialist patent law and the application of legal methods and economic levers to realistically protect and encourage invention and creation can advance China's S&T and rapidly develop the national economy. These are effective measures for strengthening the management of scientific achievements, as well as important events long anticipated by everyone. The official publication of "The Patent Law of the PRC" has deep significance both immediately and historically.

We believe that: putting into practice the written articles of the law hinges upon the basic work of earnestly making patents. Implementation of the patent law requires completion of the following fundamental work.

(1) Set up a strong and highly efficient patent literature information system. In this era of an information explosion, the scientific, economic and social value of information is increasing. The information contained in patent literature will undoubtedly become extremely valuable. If the examination and appraisal work in invention and creation is carried out apart from the patent literature, this becomes like a tree without roots, water without a source. And, when China's patent literature information system is compared to that of the world's advanced nations, the gap is very wide.

Because China has so little patent literature, few information organizations, a lack of quality service, a low rate of work efficiency and has yet to form a perfected organic, integrated information system, we are unsuited to the rapid development of patent work. According to statistics, over 90 percent of the world's new technology and new inventions are published in patent literature; annually, there are patent applications made for more than 350,000 inventions and creations, an average of about 1,000 daily. Because we have not established and perfected a patent literature network that is highly efficient at all levels, there has been much misinformation and ignorance; our scientific researchers cannot accurately, promptly and comprehensively understand the

"quotations" from the literature, so their work frequently duplicates that of other nations and people. The result is that they make futile efforts or expend twice the effort to gain half the accomplishments. In addition, in regard to inventions from some of the advanced areas of the world, we have not made application for these foreign patent rights. Moreover, for various reasons there has been a large scale giveaway of secrets and an "overseas drain" which have caused us to sustain great losses economically. Scientific research personnel engaged in inventing spend as much as one-third or even more of their time looking up data; this has given rise to the strange phenomenon of "If I don't know the length of a wall, I'll look it up if it's more than a thousand li." We must set up a strong, high-efficiency patent literature information system, with an automated and modernized system for searching that literature. Then, China's several tens of thousands of enterprises and its more than 40,000 independent research organizations above the regional or municipal level can in their inventive and creative activities see their objectives clearly; they will be able to comprehend the quotations, avoid detours, avoid blindness and onesidedness, strengthen the scientific, planned nature of their work, effect countless economies on manpower, materials and financial resources, and gain twice the accomplishments with half the effort.

(2) Train patent personnel at all levels and over a wide area.

Qualified patent personnel are the decisive factor in implementation of the patent law. In the world today there are nearly 160 nations and regions which have set up patent systems, published patent laws, and have numerous patent organizations and personnel at all levels. For example, in the Soviet Union there are 1.5 million patent literature personnel; in the United States, huge sums have been invested in training qualified people to work with patents at all levels and in the publication of a large quantity of information science and patent information books, while vigorously training university professors, S&T personnel and information specialists. The patent organizations at various levels in the industrially developed Western nations, along with some large enterprises, have set up gigantic patent information systems; these have made training patent personnel an important national policy, giving the fullest attention to their intellectual investment and developing this work. China's initial steps in this area were taken very slowly: a patent system was not even proposed here until 1978. In 1980, it was decided to establish a patent office, and in the same year China applied for admission to the United Nations World Intellectual Property Organization. The patent law was published this year. It is a matter of common knowledge that we lack people in this area. In order to better implement the patent law, we must face up to this reality, accelerate our pace, and try our best to catch up. Training patent personnel at various levels and over a wide area creates an important agenda. Mere reliance on a small number of specialists will not solve the fundamental problems. In concert with the patent law's publication, we should undertake a thorough and protracted effort in the study, dissemination and research of patent systems. Initially we want all trades and professions to have some rough idea of patent knowledge, in order to take advantage of the patent law's favorable provisions. There is much that we can draw on in the methods of the Tianjin Science and Technology Commission, which is putting particular stress on the dissemination of patent knowledge. It is doing this

by organizing a variety of study classes and public lectures, and by training patent personnel for industry, foreign trade enterprises, the judiciary, research and education organizations, etc. Meanwhile, they are carrying out a professional survey of the more than 270,000 personnel holding technical titles in 100 Tianjin units, to determine whether they are capable of using patent literature. Moreover, they are still striving for the establishment of a patent system, a working system which will cover patent application, awarding of the patent, protection of patent rights, and the provision of service. This will lay a sound foundation for implementation of the patent law.

(3) Give appropriate attention to rewards for support personnel.

China's patent law deals in an appropriate manner with national, collective and individual interests in invention and creation. Obviously, because China is a socialist nation with a focus on public ownership, the overwhelming share of patent rights pertaining to an invention belong to the unit. And, based on the significance and economic benefits of an invention or creation, the inventing unit or individuals are given certain awards and incentives proportional to the degree of their creative contribution. This embodies the principle of from each according to his abilities, to each according to his needs, and is absolutely correct. However, in the actual process of bestowing these rewards, we too often consider only the technical personnel, and overlook support personnel. This dampens the enthusiasm of support personnel to some extent. We must bear in mind that in the inventive or creative process, the hard work of support personnel is very important. This is because creative activity cannot be divorced from certain testing methods and material conditions. If support personnel do not give close cooperation and assistance, research personnel are quite helpless, and couldn't move a single step. Of course, scientific research personnel are the main force in the act of inventing, and should receive the lion's share of the reward. But in allocating awards, we want to oppose egalitarianism, "eating from the common pot," as well as avoid extremism or one-sidedness, and must mobilize fully the enthusiasm of personnel at every work station.

(4) We must ascertain the creative accomplishments of all trades and professions throughout history.

Overall, China's S&T can be termed relatively backward, but definitely not in everything. In certain fields or industries, there have emerged many creative achievements which we can unabashedly regard as up to the world's advanced level. Responsible departments and patent offices at all levels should clearly survey this new technology, these new inventions, making them fairly well known and rigorously gathering them together. Moreover, they should link these with our national conditions, formulating concrete security regulations and handling methods. Statistics demonstrate that for several years there have been about 3,000 important research achievements annually in China. It was only as recently as 1981 that the various industrial departments passed the 10,000 mark in number of new products trial-manufactured and new crafts tested. From 1979 to the beginning of 1983, Shanghai's 44 research units and

higher education institutions altogether concluded 528 technical transfer contracts, assuming responsibility for 2,347 research projects, of which more than half were to be transferred to other provinces, municipalities or autonomous regions. In keeping with the spirit of the patent law, the aforementioned research achievements and the transfer of their technology should all be progressively surveyed and handled. They should be dealt with in accordance with S&T development regulations and objective economic regulations, so that these S&T treasures can better be opened up and their utilization expanded.

12625
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SATELLITE LAUNCH SITE COMPLETED AND COMMISSIONED

Chengdu SICHUAN RIBAO in Chinese 27 Nov 84 p 1

[Article by our staff correspondent from an unidentified base]

[Text] The Commission of Science, Technology and Industry for National Defense called a meeting a few days ago to evaluate and accept the completion of a project at a certain satellite launching base. The meeting gave a high appraisal to the successful completion of this project, which assures the successful launching of the country's geostationary experimental communications satellite.

This base is a priority project for building our country's space program. It is a modernized range for which Mao Zedong, Zhou Enlai, and other veteran proletarian revolutionaries showed deep concern and on which they personally made decisions, and it is a new type of astronautical test base which the party, army, and people throughout the country paid special attention to and which they are proud of. The Commission of Science, Technology and Industry for National Defense, together with the leading party, government, and military organs in the province, where the project is located, studied specific plans, established and strengthened the organizational leadership over the project, and further strengthened the rank and file of construction workers, accelerating the construction project and perfecting a complete experimental launch system and facilities and providing favorable conditions of a modernized range for launching geostationary communications satellites.

The completion of this construction project will make tremendous contributions to the enrichment of our space program and will produce far-reaching effects on the development of our national economy and the elevation of the people's material and cultural life. The successful launching of our geostationary experimental communications satellite during the first half of this year has enabled our country to step into the world's front ranks in terms of a modernized space program. At the same time, it also indicates that the quality of this project is excellent and can meet and satisfy the needs of a modernized space program.

Participating in this evaluation and acceptance meeting were concerned leading comrades of the State Planning Commission, the State Bureau of Complete Sets of Equipment, leading comrades of provincial organs, and leading organs and bases of the military region, specially invited representatives, and

local party, government and military representatives. They heard a report on the construction project, examined the relevant data, inspected the construction site, and studied the problems concerned. They were of the unanimous opinion that with the coordination and joint efforts of all sides, the various systems of the project, and railroads, highways, and construction of leading organs are up to state acceptance standards. The project completion acceptance group which has been authorized to represent the Commission of Science, Technology and Industry for National Defense signed the relevant documents and decided to turn this project over to the state.

Staff correspondent Zhang Liquan [1728 0448 3123]

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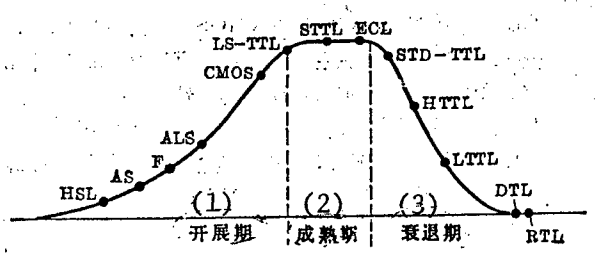
SURVEY OF INTEGRATED CIRCUITS IN CHINA

Shanghai XIANDAI TONGXIN [COMMUNICATIONS TODAY] in Chinese No 9, 1984 pp 29-30

[Article by Hao Hongan [6787 3414 1344]]

[Text] Like other electronic products, integrated circuits have a life cycle which begins with the research and development stage and then reaches a period of maximum development followed by obsolescence. Figure 1 shows the current positions in the life cycle for several internationally manufactured integrated digital logic circuits. The current state of integrated circuit (IC) fabrication in China corresponds roughly to what would be obtained by shifting each of the IC's on the curve one or two places to the left. The earliest RTL and DTL IC's are characterized by high power dissipation, a low scale of integration, and slow operating speed and poor noise immunity; production of these circuits has virtually stopped. The TTL IC's have now reached maturity and numerous varieties are being produced in large quantity. Four years ago, high-speed Schottky (AS) devices became available in the West, along with high-speed low-power (ALS) Schottky devices using TTL logic--these devices were superior to the Schottky and low-power Schottky (S-TTL and LS TTL) devices and can be used as replacements. The complementary MOS (CMOS) integrated circuits and the HCMOS (i.e., HS-CMOS) devices in the MC74HC series announced by Motorola Corp 3 years ago characterized by low power dissipation and production is currently being stepped up rapidly. In addition, HCMOS devices are tending to replace the LSTTL circuits. The emitter coupled logic (ECL) devices are remarkably fast and are widely used in mainframe computers and fast digital systems; today they are just entering the stage of maturity. Advances in the electronics industry have been accompanied by the development of fast, low-power, large-scale-integrated (LSI) devices, and the time from IC design to large-scale fabrication has decreased.



Key:
1. Development
2. Maturity
3. Obsolescence

Figure 1

Digital IC's can basically be divided into two groups--general-purpose IC's and integrated circuits of micron dimensions. These have two characteristics: they are compatible with the standard TTL (STD-TTL) devices as far as is possible, and they are easy to standardize and mass-produce. Table 1 gives the operating frequency ranges for several IC logic families, and Figure 2 plots the characteristics for some of the devices.

Table 1. Frequency Ranges of Some Logic IC's

Operating frequency	Name of IC
<100 kHz	CMOS (complementary MOS)
<30 MHz	STD-TTL, LSTTL
	ALS-TTL, HSL-CMOS
<80 MHz	S-TTL
<100 MHz	AS-TTL
>100 MHz	ECL

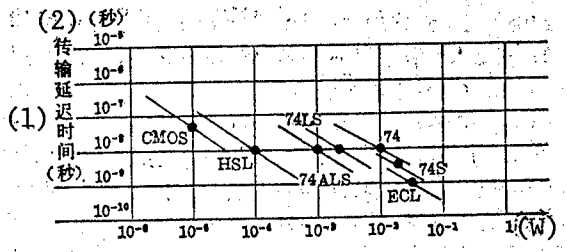


Figure 2

Key:
1. Transmission delay (s)
2. Sec

Analog integrated circuits are used to process analog signals (i.e., signals which vary continuously). Analog IC's are manufactured in profusion, but they are difficult to standardize and mass-produce (their properties are poorly reproducible) and they are expensive. The devices which have been standardized and put into large-scale production are mostly operational amplifiers, voltage regulators, and TV and audio IC's.

In short, China began producing integrated circuits in 1968 and is now capable of manufacturing all types of digital and analog IC's and many product families. Family designations have been standardized in China and products can be distinguished by their factory labels. There are many types of IC's, but they can be described in terms of the 10 categories which we discuss below.

1. Operational Amplifiers

The operational amplifiers (op-amps) produced in China have labels containing the letters CF and are essentially copies of circuits made by Fairchild Camera, National Semiconductor, RCA, Motorola, and other corporations in the United States which have become standard throughout the world, such as the μA702, 709..., CA3130, 3140, ..., LM301, 302, ..., MC1558, 3401, ..., and other devices. China's IC chips are distinguished by adding the prefix CF to the label; for example, the μA741 becomes the CF741; the label thus indicates that the two parts are completely interchangeable. Eleven of these model circuits were produced by China in 1982, some 40-odd circuits were chosen in 1983, and estimates suggest that this number will increase to over 100. The circuit models include amplifiers such as the μA733, LM170, and MC1495. In addition, some older circuits can still be found, such as the F001-F009, F011-F073 devices based on earlier Chinese studies of Western chips.

2. Voltage Regulator IC's (CW or W)

In the past, several Chinese plants designed a small number of products (such as the 5G14, W2, W610, W724) which were based on the CA3085 device. In recent years Western dc voltage regulators like the μA723, 7800/7900, LM104/105, 117/137, MC1468/1568, CA3085, and SG1511 have been selected as standard; they can be used interchangeably with other devices sold internationally. The standard designation is of the form Wxxxx, e.g., W723, W3085, etc.

3. Special-Purpose Audio and Video IC's (CD or D)

In the 1970's, Chinese plants built several kinds of devices modeled on Western products, but because of their high cost and poor quality they were mostly unsuitable for general use. During the last several years, China has been producing devices modeled on the LA4100, HA, TA series and the μPC1350C/1018C, AN7145 devices made in Japan by Sanyo, Toshiba, Hitachi, Matsushita, NEC, and others; the Chinese products are interchangeable with other devices with corresponding labels. The international family designations are of the form CDxxxx or Dxxxx.

4. Interface IC's (CJ or J)

Interface circuits are needed to design systems, particularly when analog and digital circuits must be interfaced. These devices include all kinds of drivers, analog electronic switches, monostable delay circuits, Schmitt triggers and comparators, phase-locked loops (PLL), analog-to-digital (A/D) converters, voltage-controlled oscillators (VCO), voltage frequency converters (VFC/FVC), function generators (FG), etc. The standard models generally chosen in China today are mostly dc interfaces, such as the Texas Instruments SN75000 series; the MC14433, ICL7106/7107/7126/7135, μA710, and LM311; and the ADC 08xx/1000/12xx and DAC08xx/12xx series made by National Semiconductor Corp. Chinese level comparators have the label CJ0xxx. For instance, the interface corresponding to the LM311 has the

label CJ0311; the ones corresponding to the SN7500 and SN75107 series have labels of the form CJ1xxx and CJ1107, respectively. There are some Chinese products compatible with the CD4046 which are given the label CJ4046. On the other hand, there exist a few interface devices which are conventionally classified with other circuits, such as the CD4051/4053 multichannel analog switch, which is often included in the CC4000 general-purpose CMOS family and referred to as the CC4051/4053; similarly, ECL interface circuits are often given ECL names of the form CExxxx. Older devices with the names Jxxx (e.g., the J690/691, J210/154) are also still in use.

5. Other Analog Integrated Circuits

Other analog devices which were not listed among the first four categories but cannot be classified with the digital devices include the 555/556 timer/recorder, motor controllers, the SF1212 camera controller (corresponding to the M1212), IC's used in toys and musical instruments, wrist watches, etc. These specialized circuits are very diverse.

6. TTL General-Purpose Digital IC's (CT and T)

The early DTL logic circuits evolved into the standard TTL (STD-TTL) families; the modern representatives currently in favor are the low-power LS-TTL devices. The TTL class, the largest of the digital IC categories, contains the five series listed below.

1) The T000 family, which is based on the Texas Instruments SN7400 series but not completely compatible with it. Because of its inferior performance characteristics and lack of versatility, this family is no longer being developed.

2) The T100 family is based on the SN74/5400 or STD-TTL series. These devices are directly interchangeable with their American counterparts--for example, the T1000 corresponds to the SN7400.

3) The T200 family is based on the SN74H/54H000 series (H-TTL devices), with which it is directly interchangeable. These devices are improved versions of the STD-TTL chips.

4) The T300 family is based on the SN/74S/54S000 series (the S-TTL devices), with which it is directly interchangeable. It contains Schottky TTL devices which operate at high frequencies up to 80 MHz.

5) The T400 family, which is based on the SN74LS/54LS000 series of LS-TTL devices. Again, the circuits are interchangeable with the Texas Instruments devices--e.g., the CT4112 corresponds to the SN74LS112 (dual JK flip-flop). These are low-power Schottky devices, the variety most favored today.

The noise-resistant TTL devices (that is, the HTL devices with 6V noise immunity) will be replaced by general-purpose CMOS circuits, but this has not happened yet. China has very few low-power (L-TTL) devices, and these will follow the DTL and RTL devices into oblivion. The new advanced Schottky AS-TTL devices will appear shortly.

7. General-Purpose MOS Logic Circuits (CC, CP, CN)

These devices are generally classified as CMOS, PMOS, or NMOS, depending on the fabrication technique. The only PMOS circuits still remaining are the 5G600 and the B5100 series, which are no longer being developed. They are based on the SN74000 series logic, use PMOS technology, and will be superseded by the CMOS circuits, which are faster, consume less power, and are comparable in cost. General-purpose NMOS digital IC's are not currently being fabricated, either. We see from the curve in Figure 1 that the general-purpose CMOS digital logic IC's are just now approaching full maturity. For the most part, the earlier C000 series (operating at 8-12, 7-15, and 3-18 volts) is not fully interchangeable with the CMOS devices available on the international market; some degree of incompatibility remains the rule today. China is basing its CMOS circuits on the RCA CD4000 and the Motorola MC14000 series, and the Chinese circuits are given parts names of the form CC4xxx--e.g., the Chinese counterpart of the CD4071 is the CC4071, and the CC4507 corresponds to the MC14507. The Chinese parts can be directly interchanged with the American originals.

8. The ECL Family (CE)

The Chinese ECL circuits are fabricated by 871 plants and are close copies of the Motorola 10K ECL circuit. The families now being produced include the E10100/E10500 devices and the PLL-type E12000 series, which operate at frequencies as high as 100-1000 MHz. For example, the CE12040 (the Chinese counterpart to the MC12040) is an emitter-coupled TTL logic device. This circuit does not saturate and completely eliminates charge-storage-time effects; it is also employed in common-emitter common-base stages to greatly increase operating speeds.

9. Storage Devices (CM or M)

These are classified according to their uses as ROM (read-only memory) devices, erasable read-only devices (EPROM, EEROM), write-once programmable devices (PROM), and random access devices (RAM, further subdivided into static and dynamic SRAM, DRAM devices), shift registers, etc. The circuits are also classified in terms of their fabrication technology as TTL, ECL, NMOS, CMOS, etc. Many of the memory devices today are of the NMOS type, but a trend is developing in favor of CMOS memories. These devices generally contain standard parts manufactured abroad and are used in computer memories. Chinese-made parts are provided with the prefix M but have the same numerical suffix, e.g., the M2102/2112/2114, M2708/2716/6116, M10149/10159 (equivalent to the Motorola MCM10149/10159 chip).

10. Microprocessor Chips (Cμ or μ)

The concurrent development of computers and integrated circuits is being stressed in China, which is currently capable of fabricating a 1-bit CMOS ICU microchip based on the Motorola MC14500 or an NMOS 4-bit DG040 series based on the Japanese SM-2 circuit. For several years China has been making the Intel 8080A and the Motorola 6800 chips, and production tests for devices

based on the Advanced Micro Devices 2900 series (LS-TTL chips) have been successful. The standard Chinese classification uses the prefix μ and retains the same trailing number as the original parts: e.g., μ8080, μ6800, μ2900, etc. Most of these central processing units (CPUs) are fabricated using NMOS technology; LS-TTL and CMOS are used where speed and lower power are important, respectively.

12617
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SECURE IMAGE TRANSMISSION TECHNOLOGY

Shanghai XIANDAI TONGXIN [COMMUNICATIONS TODAY] in Chinese No 9, 1984 pp 4-5

[Article by Zou Chunlin [1146 2504 2651]]

[Text] The problem of language and picture encoding has been a topic of increasing importance in modern communications and image transmission technology. Nevertheless, many areas remain to be investigated in order to find simple methods for scrambling open-circuit television transmissions.

Extensive work has been done on the processing of television picture signals and on the control and monitoring of transmission and video systems; for example, coaxial cables, optical cables, UHF radio transmitters, and microwave junctions are currently employed for image transmission. On the other hand, signal conversion to digital form is sometimes employed in order to temporarily encode video signals during image processing. The digitized signal is then converted into a sequence of pulses of various amplitude levels which are then recombined (scrambled); alternatively, an encrypting control system may be provided. In either case, transmission security can be improved enormously. However, before this method of scrambling can be fully implemented the analog image signals (which change continuously with time) must be sampled periodically (quantized), after which the series of discrete levels representing the various shades of gray must be encoded in a binary format. In order to reduce the amount of digital encoding during transmission one must also exploit the relationships that exist among the picture fields and employ line and frame prediction methods to compress the video signals. Alternatively, one can sample the signals at frequencies below the Nyquist value (2F, where F is the signal frequency). For these reasons, the standard, simple methods for scrambling picture signals are difficult to implement.

The various methods which have been suggested for overcoming these difficulties involve varying the picture synchronization signals during analog transmission in the fundamental frequency band, reversing the image polarity (white and black fields), or changing the phases of the signals. The effect of these methods is to greatly distort the signals by taking them out of step and to produce horizontal image tearing and vertical rolling so serious as to effectively scramble the signal. Moreover, the circuits required for these methods act only on the video signals output by the camera and can

therefore be added without modifying the camera circuitry, so that the properties and performance of the original system are not altered.

Depending on the specific requirements various picture scrambling methods can be combined simultaneously, or else a single method may be chosen. Most of the circuits are made up of various combinations of switching controllers. In what follows we will briefly describe how the images are processed at the transmitting and receiving terminals.

Current standards specify a picture signal amplitude of 70 percent and a blanking pulse amplitude level of 5 percent (for a total of 75 percent); the amplitude of the synchronization pulses (sync pulses) is 25 percent. During picture transmission, the 75 percent and the 12.5 percent levels demarcate the dark and light fields, respectively; the line sync and blanking pulses are 4.7 and 12 microsecond duration, and the field sync and blanking pulses are 160 microseconds and 1.28 milliseconds long, respectively. The pulse rise and fall times must be less than 0.26 and 64 microseconds, and the field frequency is 20 MHz. In view of these requirements, we see that the video picture signals consist of two parts--the analog (picture) signal and a superposed pulsed (or digital) component made up of the synchronizing and blanking pulses. During transmission, the image contains not just one but several frequencies which lie within a band of dc and ac signals at various frequencies; harmonic waves of indeterminate frequency are also present.

Image scrambling is in fact based on the composite nature of the signals--the black and white levels in the picture component for the image to be displayed can be reversed so that a negative image (like a photographic image) is received; alternatively, the positive and negative images can be fed to simple devices which mix up the dark and white areas on the screen. The sync signals can also be manipulated by suppressing the line or the frame sync signals, or a pilot signal can be added. The receiving terminal must then select the pilot frequency in order to reconstruct the picture.

In what follows we will describe how the all-video signals are converted and the pulseforms of their component signals.

Regardless of whether the average brightness of the video signal output by the camera is constant or not during transmission, the dark signal level must be kept constant. Thus it is possible for the image synchronizing and blanking signals to be reversed either from black to white or vice versa. Figure 1 illustrates how the line synchronizing and line blanking levels are removed from the all-video signal while the field synchronizing and blanking signals are left intact; a pilot frequency is added to the top part of the white signal level so as to generate a negative image with reversed synchronization.

Comparison of the pulseforms in Figure 1 (a) and (f) shows that in addition to the reversal of the synchronization signal the image has been replaced by its negative, and the line sync and blanking pulses have been eliminated and are replaced by the pilot signal.

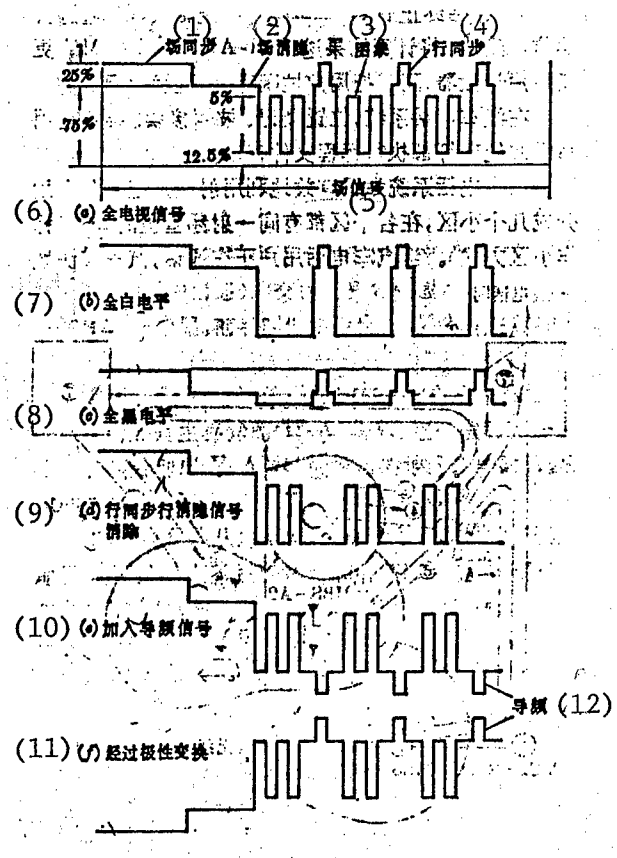

Figure 1. Conversion of All-Video Signal

Key:

1. Field sync
2. Field blank
3. Image
4. Line sync
5. Field signal
6. All-video signal
7. All-white signal level
8. All-dark level
9. Elimination of line sync and blanking signals
10. Pilot signal added
11. After polarity reversal
12. Pilot

Figures 2 and 3 below illustrate the detailed conversion process schematically. The video signal leaves the camera, enters a wide-band dc differential amplifier with one input and two outputs, and passes through a two-stage emitter repeater amplifier. These two stages output two sequences of all-video pulses which differ in polarity and phase (cf. Figure 2).

One of the two pulse trains is used as the sampling signal by the controller in the line blanking circuit and as the pilot signal by the transmission mixing and image phase mixing circuits. The other pulse train is transformed and used to modulate the positive polarity of the received picture. The line-blanking circuit contains a synchronous chopper, an amplifier, a synchronous separator, and pulse shapers, as well as a switching controller for regulating the field sync output. Finally, the sampling and the pilot

signals (standardized by the pulsewidth of the line blanking pulses) are selected independently from the line and frame pulses into which the all-video signal has been decomposed. The sampling signal is fed to the video amplifier controller and the line sync and line blanking pulses contained in the all-video signal are eliminated. The pilot signal must be modulated and output after the image has been mixed.

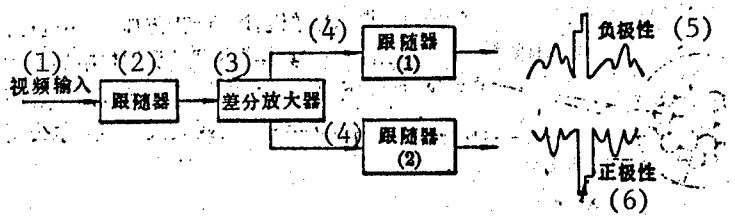

Figure 2. Block Diagram of Inverting Amplifier

Key:
1. Video input
2. Follower
3. Differential amplifier
4. Follower
5. Negative polarity
6. Positive polarity

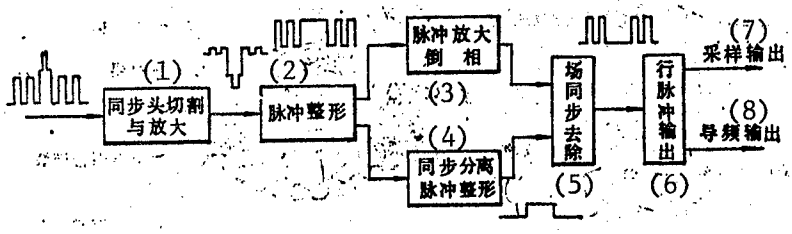

Figure 3. Block Diagram Showing Formation of Pilot Signal and Line Blanking Pulses

Key:
1. Synchronous clipping and amplification
2. Pulse shaper
3. Inverting pulse amplifier
4. Pulse former with synchronous selection
5. Field sync pulse elimination
6. Output line pulses
7. Sampling pulse output
8. Pilot signal output

After the pictures have been modified in this way they are transmitted by the sender to the receiver, where the original synchronization signals can be reconstructed simply by separating the pilot and picture signals and using a mixer circuit. In specific instances, noise suppression circuits or devices for clipping or clamping the light and dark signal levels may be employed as required. Here we should point out that it will then be necessary to select standard levels for generating and selecting the line blanking signals in the image. This is required primarily to avoid the presence of blanking levels, which can cause false triggering, spurious static dark images, or strong interference. Even though the line sync signals have

been removed, image floating associated with phase differences may still occur. In order to combat this problem, one can resort to noise-suppression circuits to stabilize the dark signal level, or one can go through the comprehensive signal processing procedure described above to solve the problem. The most convenient method is to once again alter the image frame frequency by using flip-flops (bistable circuits) and the field synchronization signal itself to optimize the circuit switching time so as to transform the image signals in one or several frames and thereby change the polarity from positive to negative. This same method can be used during reception to modulate the signal; the bistable circuits in the receiving terminal can be preset to the desired states, in which case the received pilot signal can be separated from the rest of the signal during the frame blanking period.

Finally, signal level clamping will be necessary during image processing if circuits are employed to compensate the dark levels, clip the light and dark levels, or to mix the blanking or the synchronization signals. The user terminal (receiver) can be refitted using available television broadcasting equipment, or a high-frequency converter can be added to the terminal monitor.

12617
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MEASUREMENT OF ELECTRON DENSITY BEHIND NORMAL SHOCK WAVE IN AIR

Beijing LIXUE XUEBAO [ACTA MECHANICA SINICA] in Chinese No 1, Jan 84 pp 81-84

[Article by Lui Jiping [1508 1323 1627], He Yuzhong [0149 1342 0022] and Fan Bingcheng [5400 4426 6134] of the Institute of Mechanics, Chinese Academy of Sciences: "Measurement of Electron Density Behind Shock Wave in Air"]

[Text] Abstract

The electron density behind a normal shock wave in air was measured in an 800 mm diameter low density shock tube using an improved magnetic probe and an ion collector. The results obtained are in agreement with those calculated based on the equilibrium theory by Кузнецов and Hilsenrath. At high shock Mach number Ma_s and low initial pressure, the experimental result showed an "overshoot" of electron density, which is in agreement with that of Lin Shaoji [2051 4801 1015], et al.

The ionization of air at high temperatures is usually calculated by statistical thermodynamic methods such as those documented by Предводителев,[1] Кузнецов,[2] Hilsenrath,[3] etc. The most frequently used tables belong to this category. The accuracy depends on the atomic and molecular constants used. Some work has been done on measuring the electron density behind a shock wave to verify these calculations such as the work by Lin Shaoji,[4] Баженова,[5] DeBoer[6] and Locke.[7]

In this work, the result measured in an 800 mm diameter low density shock tube using a magnetic probe and an ion collector was reported. The magnetic probe is based on the principle of Lin Shaoji[8] with improvements in three areas: (1) A fine nylon (or glass) tube with a permanent magnet and a pickup coil inserted into the shock tube was used to improve the resolution, because the magnetic field was confined in a small region. (2) At low densities and with a strong permanent magnet, the electron spinning frequency was increased or became comparable to the collision frequency so that Hall effect current could not be neglected. (3) Aluminum was used to calibrate the basic parameters of the probe (sensitivity and spatial resolution) under normal electric conduction, as well as the response characteristics of the probe. In addition, the magnetic field distribution of the probe and electromagnetic

theory were used to find the magnetic probe response at low collision frequencies in a strong magnetic field.

The inductive voltage V caused by a semi-infinite conductor with an electric conductivity σ_0 passing through the probe at a speed u (center positioned at x) can be written:

$$V(x-s) = u\sigma_0 g(x-s) \tag{1}$$

where s is the position of the conductor surface and the function g(x-s) is related to the magnetic field and the geometric shape. It was calibrated with a metal (with known conductivity and speed). It was found to be a normal distribution function:

$$g(x-s) = \frac{A^*}{\sqrt{2\pi}} e^{-\frac{1}{2}\left[\frac{\sqrt{2}(x-s)}{b}\right]^2} \tag{2}$$

where A^* and b are probe constants expressing its sensitivity and resolution distance, respectively.

For a conductive gas, the spinning frequency could not be neglected. It should be considered together with the expressions for the spatial magnetic field and electrical conductivity. The value of the response function at the center should be:

$$g_B(0) = g(0)\left(\frac{\nu}{\omega_{b_0}}\right)\left(\frac{\pi}{2} - \mathrm{tg}^{-1}\frac{\nu}{\omega_{b_0}}\right) \tag{3}$$

where ν is the collision frequency and ω_{b0} is the spinning frequency corresponding to the magnetic field strength at the center of the probe surface. The two wings of g_B are more complex. The decline is more gradual and flat with decreasing ν/ω_{b0} as compared to that of a normal distribution.

When ω_{b_0} is much larger than ν, it can be written as

$$g_B(x-s) = \begin{cases} g(0)\dfrac{\nu}{\omega_{b_0}}\left(\dfrac{\pi}{2} - \mathrm{tg}^{-1}\dfrac{\nu}{\omega_{b_0}}\right) & |x-s| < b_H \\ 0 & |x-s| > b_H \end{cases} \tag{4}$$

where b_H is the effective width of the magnetic probe. According to actual measurements, $b_H = 2b$. In equation (4), when ν/ω_{b0} is small $\mathrm{tg}^{-1}\,\nu/\omega_{b0}$ can be neglected. The normal expression for electric conductivity is[8]

$$\sigma_0 = 0.850\frac{n_e e^2}{m_e \nu} \tag{5}$$

where n_e is the electron density. Since h_e varies gradually behind the wave, we get

$$V(t) = 0.850 \frac{\sqrt{\pi}\, b_H e^2 u}{\sqrt{2}\, \omega_{b_0} m_e} A^* \frac{dn_e}{dt} \tag{6}$$

where A^* is a constant related to D, which could be determined by a regular conductive metal. The inductive voltage could be directly recorded. n_e would be obtained either by digital integration or direct conversion by an integrator. The magnetic probe technique was reported in detail elsewhere.[9]

The ion collector used in the experiment was made of glass. The tip of the glass tube was shaped into a hollow cone with a 15° half span angle. A small sharp edged hole, 0.1 mm in diameter, is located at the top of the cone. The Knudsen's number was greater or close to 1 for the flow behind the shock wave in the experiment. The collector acted as a Kantrowitz-Grey skimmer.[10]

The inner wall of the collector was silver plated as a collector electrode. Usually -22.5 V vs ground is applied. Electrons are repulsed by the negative potential at the inlet. Only ions and neutral molecules can enter. After ions are absorbed by the electrode, it acts as a Faradaic tube which receives an ionic current and provides an output through a source follower. According to the free molecular flow theory,[11] the ionic current can be written as

$$I_i = \frac{eAn_i\bar{c}}{4} [e^{-s^2} + \sqrt{\pi} S(1 + \mathrm{erf} S)] \tag{7}$$

where A is the inlet cross-section, c is the average ionic thermal motion speed, n_i is the ionic concentration, $s = u/\bar{c}$, and u is the speed of the fluid. When S is large, equation (7) can be transformed into

$$I_i = eAn_i u \tag{8}$$

The reported experiment also satisfied this relation.

This collector is different from that used by DeBoer.[6] In reference 6, a continuous sampling flow was used while a molecular flow was used in this work. A detailed description is reported separately.

In this work, the shock tube was evacuated to 5×10^{-4} torr. The leakage rate was less than 5×10^{-5} torr. The air used was mixed in a standard container using 99.9 percent pure N_2 and 99.6 percent pure O_2. The time between the end of pumping and the shattering of the diaphragm was less than 5 minutes. The shock wave speed was measured by a five channel microsecond timer and the error was less than 2 percent.

The electron density behind the shock wave was measured within the range from 10 to 19 Mach numbers and 10^{-2} to 1 torr in initial pressure P_1. The experimental results are plotted in Figure 1. The theoretical curves in the figure were equilibrium electron densities calculated from the Предводителев table. Figure 2 shows experimental points obtained at 2×10^{-2} torr in this work, as well as those obtained by Lin. The curves were obtained by calculation

based on the equilibrium theories developed by Предводителев,[1] Кузнецов,[2] and Hilsenrath,[3] as well as on the nonequilibrium electron "overshoot" theory of Lin Shaoji. It should be pointed out that there is not much difference in the equilibrium results presented in references 1-3. (The electron density given by the Предводителев table is slightly lower because the ionization potential used is 9.5eV, which is higher than the currently adopted 9.5eV.) However, a larger electron density was obtained by the nonequilibrium electron "overshoot" method, which was confirmed experimentally in Lin's work.

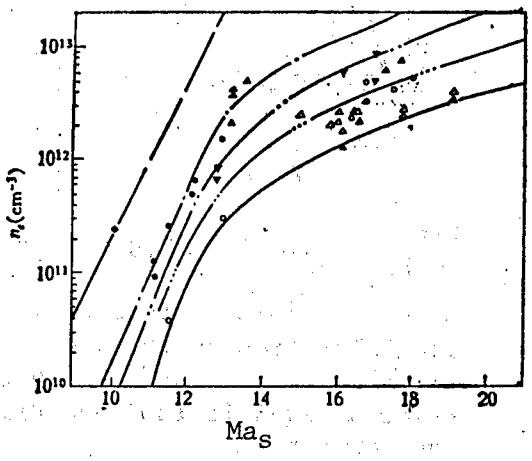

Figure 1. Electron Density n_e vs. Ma_s

P_1 torr		
Δ, o	1.9×10^{-2}	magnetic probe, ion collector
Δ	3.8×10^{-2}	magnetic probe
▼	7.6×10^{-2}	magnetic probe
▲, o	1.3×10^{-1}	magnetic probe, ion collector
★	9.1×10^{-1}	magnetic probe

— —	1	
—•••—	3.8×10^{-2}	
—•—•	7.6×10^{-2}	from reference 1
— • —	1.3×10^{-1}	
———	1.9×10^{-2}	

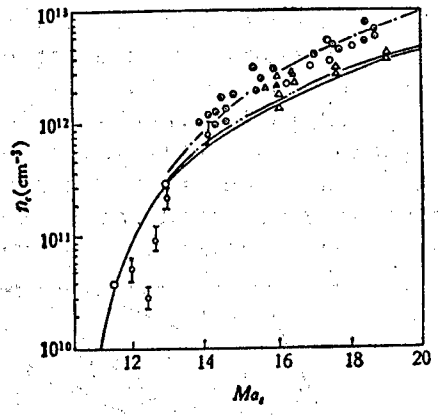

Figure 2

⊖ Lin[6]
⊖ Locke[7] $P_1 = 2.0 \times 10^{-2}$ torr
Δ magnetic probe in this work
o ion collection in this work $P_1 = 1.9 \times 10^{-2}$ torr
—•— electron "overshoot" theory by Lin[6]
—• •— Кузнецов equilibrium[2] and Hilsenrath equilibrium[3]
——— Предводителев[1]

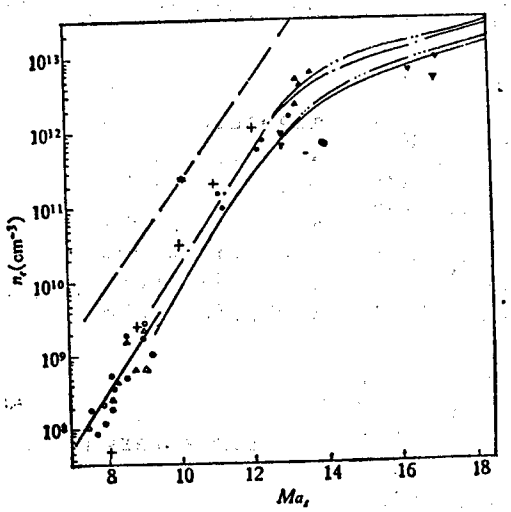

Figure 3

P	(torr)		
+	7.6×10^{-1}	Баженова	
&	1.0×10^{-1}	DeBoer	
●	This work	1.3×10^{-1}	ion collector
▲	This work	1.3×10^{-1}	magnetic probe
▼	This work	7.6×10^{-2}	magnetic probe
★	This work	9.1×10^{-1}	magnetic probe

— — [2][3] 1.0 —•••— [2][3] 7.6×10^{-2}
—•— [1]1.3×10^{-1} ——— [1]
—• •— [2][3] 1.3×10^{-1} ——— [6] 1.0×10^{-1}

In this work, an electron density overshoot was observed at $Ma_s = 16$. However, the value is lower than that measured by Lin. Figure 3 shows the results at higher initial densities, which are in agreement with theoretical predictions. Furthermore, it showed good continuity with DeBoer's results at lower Mach numbers. The results of Баженова,[5] however, is approximately half a magnitude lower.

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TECHNICAL CALCULATION METHOD OF SHAPED CHARGES

Beijing BINGGONG XUEBAO [ACTA ARMAMENTARII] in Chinese No 1, Feb 84 pp 1-11

[Article by Hu Huanxing [5170 3562 1840], Li Dejun [2621 1795 0193] and Chen Shiyu [7115 0013 6877]]

[Text] Abstract

The calculation method (the JPGS algorithm) presented here treats all the geometric parameters of the cartridges of shaped charges and their liners as well as the density, detonation velocity and multiple power index of explosives. An incompressible flow model is used in the calculation of the collapse and jet parameters. The collapse velocity is calculated for a flat plate projection model and is modified by the results of cylindrical cohesive collapse tests. Penetration is calculated in accordance with quasi-steady process and the effects of target strength and break-up of jets are also considered. The calculated results of collapse parameters of various charges, jet parameters and penetration process indicate that the calculated values are in good agreement with the measured values.

Using the JPGS algorithm, we cannot only calculate the parameters for currently used charges and predict the performance of new charge designs but also make quantitative analysis of the effects of the various parameters on the penetration.

1. Introduction

To a large degree, the penetration ability of a shaped charge depends on the design of the charge. The equations used for calculating the jet parameters and penetration are difficult to apply to realistic charge designs because they did not take into account the geometric parameters and the explosive performance of the charge. Although the two-dimensional axially symmetric HELP and HEMP codes can calculate the jet formation process and the penetration process numerically, they cannot model the entire process for the shaped charge due to machine capacity and computation time limits.

Using the equations and procedures presented in this paper, we can calculate all the parameters from the collapse to the jet formation once the geometric parameters of the shape, liner material density, charge characteristics (density, explosion speed, multiple power index and propulsion parameters) and detonation location are given. If the explosion height and the target parameters are also given, the penetration process can also be calculated.

2. Model and Equations

2.1 Description of the collapse process and calculation of the collapse speed.

2.1.1 Discussion of the flat plate model

The collapse process of the liner has been discussed in Refs. 1 and 2 using hydrodynamics theory. The collapse process may be approximated by the projection of a metal plate covering a platelike charge. Under this assumption, the complicated explosion process may be treated as a simple two-dimensional steady flow and the analytical expressions may be developed to describe the collapse of the liner. The following assumptions are made in the discussion: (1) under the high pressure of the explosive products, the collapsing metal material is taken to be an incompressible fluid and the deformation energy is ignored, (2) the explosion load on an element of the collapsing metal depends only on the thickness of the charge corresponding to the element and the mode of explosion, and (3) the effects of the boundary conditions are ignored and the product is viewed as a two-dimensional steady flow.

In reality the collapse of the liner is a situation between the collapse of the metal tube liner by a tubular charge and the collapse of a metal plate by a plate charge. A comparison shows that they have exactly the same picture and their collapse velocities are also similar. Therefore, the shaped charge may be simplified as a plate charge in our discussion.

2.1.2 Approximation theory in the calculation of the collapse velocity V_0

When the detonation wave sweeps across the liner surface and the incidence angle i varies over a range, the collapse process of the liner is not invariant. But when an element S of the liner is expanded into an infinitely large plate charge of explosive thickness t_e and plate thickness t_p and the incidence is kept a constant, then the collapse of the plate is fixed. The collapse diagram is shown in Figure 2.1.

If we approximate the gradual deflection process of the metal plate by the deflection angle φ at the maximum velocity, that is, in the study of the state after the energy conversion, we have the following relations that can be deduced from geometric relationships.

$$V_0 = 2U\sin\frac{\varphi}{2} \tag{2.1}$$

$$U = D/\sin i \tag{2.2}$$

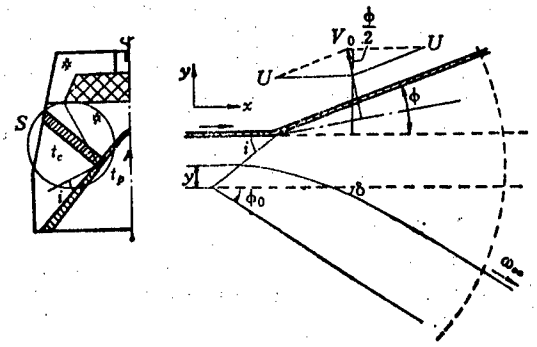

Figure 2.1. Liner Element and the Fixed Collapse of the Metal Plate

where D is the explosion speed of the explosive. For the collapse of a plate, the approximate analytical expression of angle φ is

$$\frac{1}{\varphi}=\frac{1}{\varphi_0}+C\mu \tag{2.3}$$

where φ_0 is the deflection angle of the explosion products, $C=WD\rho_e/p_H$ (here, ρ_e is the density of the explosive, p_H is the pressure of the explosion front and W depends on the material parameters of the explosive, and C is a parameter related to the properties of the explosive and $\mu=\frac{\rho_p t_p}{\rho_e t_e}$ is the mass ratio of the metal plate and the explosive, ρ_p is the density of the plate.

The experimental results of $\frac{1}{\varphi}$ versus μ are shown in Figure 2.2. If Equation 2.3 is viewed as a linear relationship, then,

$$\frac{1}{\varphi}=b+C\mu \qquad \left(b\approx\frac{1}{\varphi_0}\right) \tag{2.4}$$

and the energy E acquired by the metal plate propelled by a unit mass of the explosive,

$$E=\frac{1}{2}\mu V_0^2=\mu U^2(1-\cos\varphi) \tag{2.5}$$

Taking the extremum of the above equation, we have $\mu_m=\frac{b}{C}$, $V_m=2U\sin\frac{\varphi_m}{2}$ corresponding to $E_{max}=\frac{1}{8}\frac{U^2}{bC}$. Thus,

$$b=\frac{U}{2V_m},\quad C=\frac{U}{2\mu_m V_m} \tag{2.6}$$

Based on Figure 2.1, we can write down the momentum equilibrium in the field:

$$\begin{cases}\mu(1-\cos\varphi)+1=\dfrac{\omega_\infty}{Ut_e}\displaystyle\int_0^{t_e}\cos\delta dy\\ -\mu\sin\varphi=\dfrac{\omega_\infty}{Ut_e}\displaystyle\int_0^{t_e}\sin\delta dy\end{cases} \tag{2.7}$$

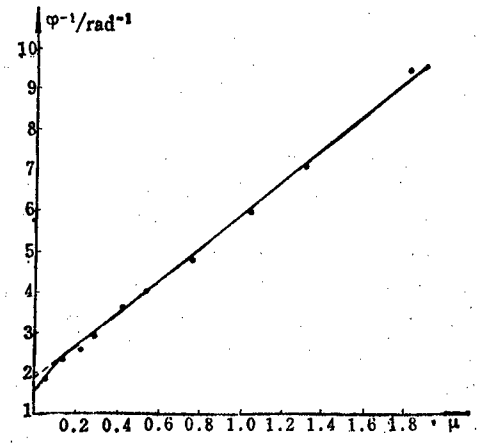

Figure 2.2 The Experimental $\frac{1}{\varphi} - \mu$ Curve

When the pressure at a given radius in the flow of the explosion product is uniform in time, then, integration of the above equation leads to

$$E = -\frac{3U(\omega_\infty - U)}{4\mu\frac{U}{\omega_\infty} + 5 + \frac{\omega_\infty}{\mu U}}$$

and $$\mu_m = -\frac{\omega_\infty}{2U}, \quad V_m = 2U\sqrt{\frac{1}{3}\left(1 - \frac{U}{\omega_\infty}\right)}, \quad \omega_\infty = U\sqrt{\frac{\Gamma^2 - \cos^2 i}{\Gamma^2 - 1}}$$

By substituting the equations above into Equation 2.6, we have the analytic solutions for b and C.

$$b = \frac{\sqrt{3}}{4}\left(1 - \sqrt{\frac{\Gamma^2 - 1}{\Gamma^2 - \cos^2 i}}\right)^{-\frac{1}{2}} \tag{2.8}$$

$$C = \frac{\sqrt{3}}{2}\left(\frac{\Gamma^2 - \cos^2 i}{\Gamma^2 - 1} - \sqrt{\frac{\Gamma^2 - \cos^2 i}{\Gamma^2 - 1}}\right)^{-\frac{1}{2}} \tag{2.9}$$

where Γ is the multiple power index of the explosion products, ω_∞ is the velocity when the explosion products reach a maximum. Ignoring second order small quantities, we have, for $i = \frac{\pi}{2}$,

$$E_{max} \approx \frac{1}{6}\frac{D^2}{\Gamma^2 - 1/2}$$

This means that the performance of the explosion is roughly directly proportional to the squares of the explosion velocity, and inversely proportional to the squares of the multiple power index. The value of Γ is the average of the value at the explosion surface and the Γ value required to accelerate the metal plate to its maximum velocity.

2.1.3 Effects of the boundary condition and determination of the experimental parameters

Since the explosion of the charge takes place in the atmosphere and the charge has a finite size, we must study the effects of the atmosphere and the boundary condition on the collapse velocity. Generally we may treat the problem by including a term in the momentum conservation equation equivalent to adding an inertia mass on top of the charge plate. Obviously, this would decrease the jet deflection angle Ψ_0 and the metal plate bending angle Ψ. Assuming the incidence angle i, the atmospheric medium and the boundary condition have the same relative effect and b and C, then, the modified expressions for b and C are as follows:

$$b = b_j \left(\frac{1 - \frac{1}{\Gamma}\sqrt{\Gamma^2 - 1}}{1 - \sqrt{\frac{\Gamma^2 - 1}{\Gamma^2 - \cos^2 i}}} \right)^{1/2} \tag{2.10}$$

$$C = C_j \left[\frac{\Gamma^2 - 1}{\Gamma^2 - \Gamma\sqrt{\Gamma^2 - 1}} \left(\frac{\Gamma^2 - \cos^2 i}{\Gamma^2 - 1} - \sqrt{\frac{\Gamma^2 - \cos^2 i}{\Gamma^2 - 1}} \right) \right]^{-1/2} + C_a \left(C_b \frac{t_a}{L} - 1 \right) \tag{2.11}$$

where b_j is the experimental interception distance at $i = \frac{\pi}{2}$ and C_j is the experimentally obtained slope in the atmosphere at $i = \frac{\pi}{2}$ extrapolated to an infinite plate. C_a, C_b and L are experimentally determined coefficients and they are regarded as the effects of the relative thickness of the charge plate in our experimental study of the boundary condition effects.

Under the conditions just described ($i = \frac{\pi}{2}$), we conducted experiments using different explosives and plate thicknesses. Table 2.1 shows the material parameters of two typical explosives and experimentally obtained propulsion parameters.

Table 2.1. Explosion Parameters and Experimentally Determined Coefficients for Two Typical Explosives

Explosive	$\rho_e/(\mathrm{gcm^{-3}})$	$D/(10^3\mathrm{m\cdot s^{-1}})$	Γ	$Q/(\mathrm{K\cdot g^{-1}})$	b_j	C_j	C_a	C_b	L
Explosive No 1	1.69	7.8	2.63	955	1.68	3.30	5.28	1.12	5.0
Explosive No 2	1.64	8.24	2.72	1076	1.77	3.51	0.82	1.36	5.0

2.1.4 Simplified collapse model and calculation

As discussed earlier, the collapse velocity of a shaped charge should correspond to a state between a plate collapse and a circular pipe cohesive collapse. Therefore, we simplify the collapse of a shaped charge to the collapse of the tubular metallic liner by a tubular charge.

We performed collapse experiments using four different thicknesses in a 30 mm inner diameter tubular charge on eight different thicknesses of copper tubes, the results are shown in Figure 2.3. To obtain the effect of the charge size, we plotted the slopes in Figures 2 and 3 as a C_{ju}' versus t_e curve in Figure 2.4.

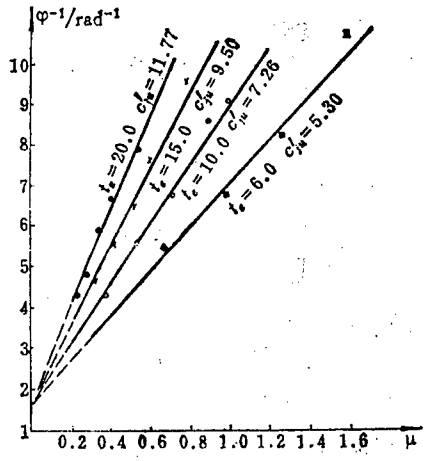

Figure 2.3. $\frac{1}{\varphi}$ versus μ Curve for the Collapse of a Circular Tube Charge. (The explosive charge has a length of 120 mm, an inner diameter of 30 mm and the thicknesses of the copper tube are 0.10, 0.26, 0.90, 1.90, 2.40, 2.90 and 3.90 mm)

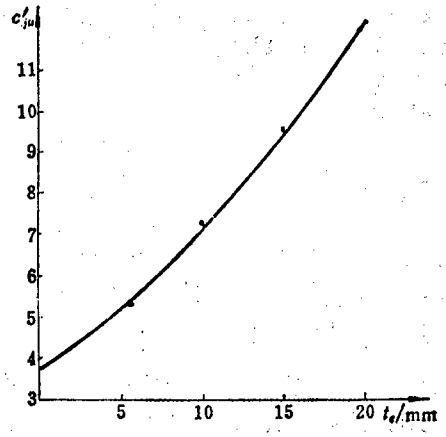

Figure 2.4. C_{ju} versus t_e Curve Based on Figure 2.3

The results show that, within experimental error, the intercept b_j of the two models are equal and only the slopes are different. The slopes of tube collapse should be greater than the collapse of a plate of equal thickness, that is, for the same μ, the collapse velocity of the tube should be smaller. Thus, whether the simplification uses a plate model or a tube model, the obtained results are different from the actual collapse velocity. Therefore, in the calculation of the collapse velocity of a shaped charge, the slope expression may be further modified as follows to take into account the axially symmetric implosion situation:

$$C = C_j\left[\frac{\Gamma^2-1}{\Gamma^2-\Gamma\sqrt{\Gamma^2-1}}\left(\frac{\Gamma^2-\cos^2 i}{\Gamma^2-1}-\sqrt{\frac{\Gamma^2-\cos^2 i}{\Gamma^2-1}}\right)\right]^{-1/2}$$
$$+C_e\left[C_b^{\frac{t_e}{L}\left(1+Z_0\sqrt{\frac{R_e^2-R_N^2}{R_N^2}}\right)}-1\right] \qquad (2.12)$$

where R_N and R_e are respectively the inner and outer radii of the charge element and Z_0 is a coefficient.

2.1.5 Calculation of the incidence angle i

For charges without a partition wall, the incidence angle of the blast is

$$i = \alpha_1 - \alpha_y = \mathrm{arctg}\left(-\frac{h_s + g}{R_s}\right) + \pi - \alpha_y$$

For charges with a partition wall, the partition changes the waveform of the main charge and delays the explosion. Based on experimental results, the average shock wave velocity D_m in the partition is given by the following empirical equation:

$$D_m = \left(A_0 - B_0 \frac{H_g}{H_0}\right)\sqrt{\rho_{e1} D_1 / \Gamma_1} \qquad (2.13)$$

where H_g is the partition thickness, H_0, ρ_{e1}, D_0 and Γ_1 are respectively the height, density, explosion velocity and the multiple power index of the main charge, and A_0 and B_0 are numerical coefficients.

For type FS-501 material, ρ = 1.24 g/cm^3, A_0 = 77.70, B_0 = 20.90. For fibrous plastic, ρ = 1.8 g/cm^3, A_0 = 79.00 and B_0 = 5.37. For plastic foam, ρ = 0.2 g/cm^3, A_0 = 89.95 and B_0 = 39.51.

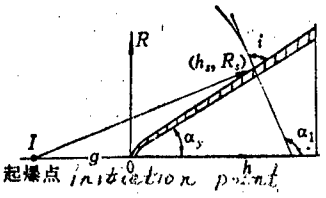

Figure 2.5. Calculation of the Incidence Angle for Charges Without Partition

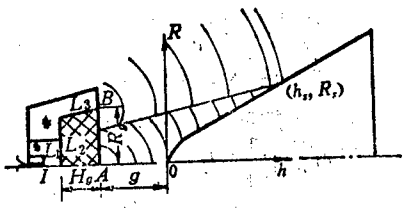

Figure 2.6. Calculation of the Explosion Waveform With a Partition

As shown in Figure 2.6, the explosion begins at point I and the time required for the shockwave to reach point A is $T_1 = \frac{L_1}{D_1} + \frac{H_g}{D_m}$. The time required for the blast wave to go around the partition and reach point B is $T_2 = (\sqrt{L_1^2 + L_2^2} + L_3)/D_1$.

If $\Delta T = T_1 - T_2 = 0$, then A and B explode simultaneously and the locus of the intersection of the two waves is $R = R_g/2$. For any point on the surface with $R_S \leqslant R_g/2$, the spherical waves are calculated with A being the center; otherwise, B is taken to be the center. Let $T_3 = R_g/D$ (D is the explosion velocity of the main charge), then, the calculation assumes B to be the initiation point when $\Delta T \geqslant T_3$. If $\Delta T \leqslant 0$ and $|\Delta T| \geqslant T_3$, then A is taken to be the initiation point. If $|\Delta T| \leqslant T_3$, then source A and source B meet at some point between A and B and the locus of the intersection is

$R = \left(R_g^2 - 2D(g+h)\Delta T - D^2\Delta T^2\right)/2R_g$. When $R_S \leqslant R_1$ A is the source; otherwise, B is the source.

2.2 Formation of the jet and the pestle and the calculation of parameters

2.2.1 In the explosion the liner collapses and the inner layer finally forms the jet and the outer layer forms the pestle. Under the plane flow condition, the equation for calculating the jet parameter (V_j, M_j) and the pestle parameter (V_N, M_N) are

$$\left.\begin{aligned} V_j &= V_0 \frac{\cos\left(\alpha + \frac{\varphi}{2} - \frac{\beta}{2}\right)}{\sin(\beta/2)} \\ V_N &= V_0 \frac{\sin\left(\alpha + \frac{\varphi}{2} - \frac{\beta}{2}\right)}{\cos(\beta/2)} \\ M_j &= \Delta m \sin^2\frac{\beta}{2} \\ M_N &= \Delta m \cos^2\frac{\beta}{2} \\ \Delta E_j &= \Delta E \cos^2\left(\alpha + \frac{\varphi}{2} + \frac{\beta}{2}\right) \end{aligned}\right\} \tag{2.14}$$

$$\operatorname{tg}(\beta-\alpha) = \frac{\frac{1}{R}[\sin(\alpha+\varphi)-\sin\alpha]\sin\varphi - \frac{1}{U}\sin\varphi\frac{dU}{dS} + (1-\cos\varphi)\frac{d\alpha}{dS} - \cos\varphi\frac{d\varphi}{dS}}{\frac{1}{R}[\sin(\alpha+\varphi)-\sin\alpha]\cos\varphi + \frac{1}{U}(1-\cos\varphi)\frac{dU}{dS} + \sin\varphi\left(\frac{d\alpha}{dS}+\frac{d\varphi}{dS}\right)} \tag{2.15}$$

where β is the compression angle, Δm is the mass of the element, ΔE_j and ΔE are respectively the kinetic energy of the jet and of the liner, R is the outer radius of the element and S is the bus-bar coordinate along the liner.

2.2.2 Assuming that Δm forms a jet element at point 0' at time t_z and the element moves in a striahgt line with a uniform velocity V_j (see Figure 2.7), then, at $t_j > t_z$, the position of the jet particle is given by

$$Z_j = Z_0(t_z) + (t_j - t_z)V_j(t_z)$$

where Z_0 is the initial coordinate of the element. The length of the jet at time t_j is

$$dZ(t_j) = dZ_0 + (t_j - t_z)dV_j - V_j\,dt_z$$

and the radius of the jet is

$$r_j = \sqrt{\frac{M_j}{\pi\rho_j \partial Z/\partial t}}$$

where ρ_j is the density of the jet.

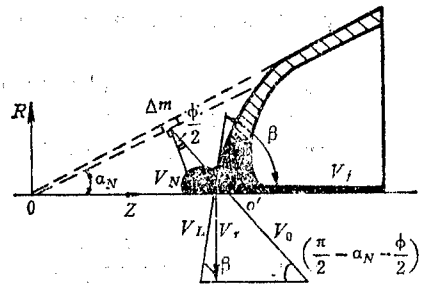

Figure 2.7. Formation of the Jet and the Pestle

When the converging velocity V_L is greater than the speed of sound c_0 in the material, the jet cannot be formed effectively. When $V_L=V_0\cos\left(\alpha+\frac{\varphi}{2}\right)/\sin\beta$, i.e., $V_0\geqslant\frac{c_0\sin\beta}{\cos(\alpha+\varphi/2)}\left(\text{or }\alpha\geqslant\varphi\left(\frac{D}{c_0\sin i}-1\right)\right)$ the jet cannot be formed. In addition, at the opening of the charge the collapse velocity is generally very low and experiments have shown that, when the radial component satisfies the following condition

$$V_r=V_0\cos\left(\alpha+\frac{\varphi}{2}\right)\leqslant 1200\,\text{m/s} \tag{2.16}$$

the liner elements will not converge to the axis but fly apart. Equation 2.16 gives the limiting condition for the formation of the jet tail velocity.

Normally the jet elements first formed do not possess the maximum jet velocity. Close to the top of the liner, some elements cannot form jet because their V_L is too large. Therefore, the jet particles near the top will collide and build up and finally form the following jet head velocity V_{jo} according to momentum conservation.

$$V_{j_0}=\frac{\Sigma(M_jV_j)}{\Sigma M_j} \tag{2.17}$$

where ΣM_j is the sum of the accumulated jet mass.

2.3 Calculation of the penetration process

2.3.1 Analysis of the jet penetration in target plates of various strength and density shows that: (1) The jet penetration process can apparently be divided into three stages, the first 10 percent of the penetration is the funnelshaped open pit, the next 80 percent of the penetration is the quasi-constant penetration region and the last 10 percent at the bottom of the hole contains a large amount of debris. The accumulation of debris increases with the jet velocity until the jet loses its penetration power. (2) The deformation of the plate is mainly caused by shear and hole expansion and the resistance to deformation is mainly the yield strength of the material under high pressure and high stress rate, while the temperature effect may be neglected. (3) The penetration depth and the hole diameter increase as

the density of the target material decreases and decreases as the tensile strength of the target material increases, but the relationship is not linear.

We assume that the entire penetration process is quasi-steady,[3] as shown in Figure 2.8. The continuous jet reaches the target at time T_0 and the jet element V_j reaches the bottle of the hole at time T_j, the penetration depth L_p is given by

$$L_p = V_j T_j - x_0(V_j) \tag{2.18}$$

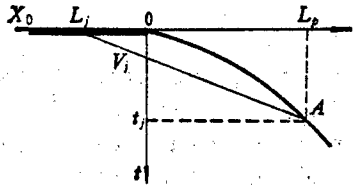

Figure 2.8. The Penetration of a Continuous Jet

After differentiating with respect to V_j and simplifying the expression, we have

$$\frac{dT_j}{dV_j} + \frac{T_j}{V_j - u} - \frac{1}{V_j - u}\frac{dx_0}{dV_j} = 0 \tag{2.19}$$

where u is the penetration velocity. Measurements on steel targets of different strength gave

$$\left.\begin{aligned} u &= \frac{V_j}{1+\sqrt{\rho_t/\rho_j}} && (V_j \geqslant 2.5V_{cR}) \\ u &= \frac{V_j\sqrt{1-(V_{cR}/V_j)^2}}{\xi\left(1+\sqrt{\rho_t/\rho_j}\right)} && (V_j < 2.5V_{cR}) \end{aligned}\right\} \tag{2.20}$$

where ρ_j and ρ_t are respectively the densities of the jet and of the target plate, ξ is an experimental coefficient, V_{cr} is the critical penetration velocity and is equal to $\sqrt{\sigma_b/28}$, and σ_b is the tensile strength of the target. Using the initial condition that $V_j = V_{j0}$ at $T_j = 0$, the solution of Equation 2.19 is

$$T_j = \exp\left(-\int_{V_{j0}}^{V_j}\frac{dV_j}{V_j - u}\right)\int_{V_{j0}}^{V_j}\left[\exp\left(\int_{V_{j0}}^{V_j}\frac{dV_j}{V_j - u}\right)\frac{\frac{dx_0}{dV_j}}{V_j - u}\right]dV_j \tag{2.21}$$

Substituting Equation 2.21 into Equation 2.18, L_p can be solved. The radius of the hole is

$$r_p = \sqrt{\frac{\Delta E_j}{k\pi\sigma_b\rho_t\Delta L_p}} \tag{2.22}$$

where ΔL_p is the penetration depth of the jet element and k is a constant.

2.3.2 Near the late stage of the penetration the tail jet often breaks up because of overstretching. The discontinuous jet particles must open new holes in their penetration and they are likely to be disturbed and miss the bottom of the hole. Such factors reduce the penetration power of the interrupted jet.

Suppose the jet element $V_{j[K]}$ is broken at time T_D, and the particles reach the bottom of the hole at time $t_{D[K]}$ and finish the penetration at time $t_{[K]}$. The previous jet element completes its penetration at time T. Obviously $T > T_D$. Based on the measurement results of the jet interruption time of shaped charges with various apex angles, the formula for calculating the free jet interruption time T_D may be modified as follows (after Zheng Zhemin [6774 0772 2404]):

$$T_D = A\alpha^{2/6}\left(\frac{r_{j_0}}{\Delta V_j}\right)^{1/3} \tag{2.23}$$

where A is a constant, r_{j_0} and ΔV_j are respectively the initial radius of the jet and the initial velocity gradient. As shown in Figure 2.9, the hole depth when the particle length $\Delta\ell_{[K]}$ is dissipated is given by

$$\Delta L_p = \frac{\Delta l_{(K)}}{V_j/u - 1}\cos\psi \tag{2.24}$$

where $\cos\psi$ is a correction term to account for the reduction in penetration power due to interruption, ψ is equivalent to the scattering angle of the particle.

$$\psi = A_0'\left(\frac{\Delta l_{(K)}}{l_0}\,\frac{t_{D(K)} - T_D}{T_D}\right)\Big/ M_a^2\,\frac{r_j}{r_{j_0}}$$

The initial length of the jet element is ℓ_0, $t_{D[K]}$ is the time when element k hits the target, r_j is the contact radius, M_a is the Mach number of the jet $A_0' = 4.5$.

The target hole radius for the interrupted penetration can still be calculated using Equation 2.22 but a different value must be assigned to the constant.

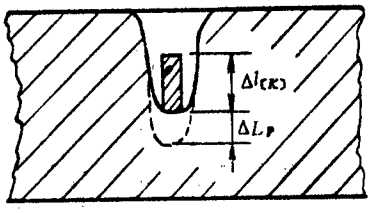

Figure 2.9. Penetration of an Interrupted Jet

3. Computer Program and Sample Analysis

3.1 The JPGS program is used on the DJS-6 computer using the ALGOL codes. The program calculates the penetration process of a stationary shaped charge without a shell or with a very thin shell. The block diagram of the program is given in Figure 3.1. The formulas used in the program have been explained earlier.

The value of μ as calculated from the geometric relationship of the charge is

$$\mu = \frac{\Delta m_p}{\Delta m_e} = \frac{m_{p(j)} - m_{p(j-1)}}{m_{e(j)} - m_{e(j-1)}}$$

The masses of the cover element and the charge are respectively Δm_p and Δm_e. Subscript j is the index of the surface element along the outside of a vertical shaped charge, $m_{p[j]}$ and $m_{e[j]}$ are the masses of all the elements before the jth element.

3.2 Using the JPGS code, we made calculations for more than 10 different shaped charges and compared with experimental results. The charge diameter ranged from 25 mm to 145 mm, the conical angle range is 42° - 70° and some have a single cone and others have a double cone. We shall now analyze a few cases, see Figures 3.2-3.5.

Even though the combined variation and scattering in the explosive charges and in the measurements amounted to about 10 percent, the calculated curve basically falls in the middle of the experimental data. This shows that the theory and the experiment are in good agreement. The calculated results show that:

(1) The collapse velocity gradient changes considerably near the top, sometimes two peaks are clearly seen. This often causes instability in the early formation of the jet and increases the pile-up region. The structural design should minimize the separation between the fluctuating gradient and the peak value in the V_0 distribution.

(2) Because the jet formed by the cone causes the accumulation of debris, one-third of most charges do not form jets. The extent of the accumulation varies greatly for different cone structures.

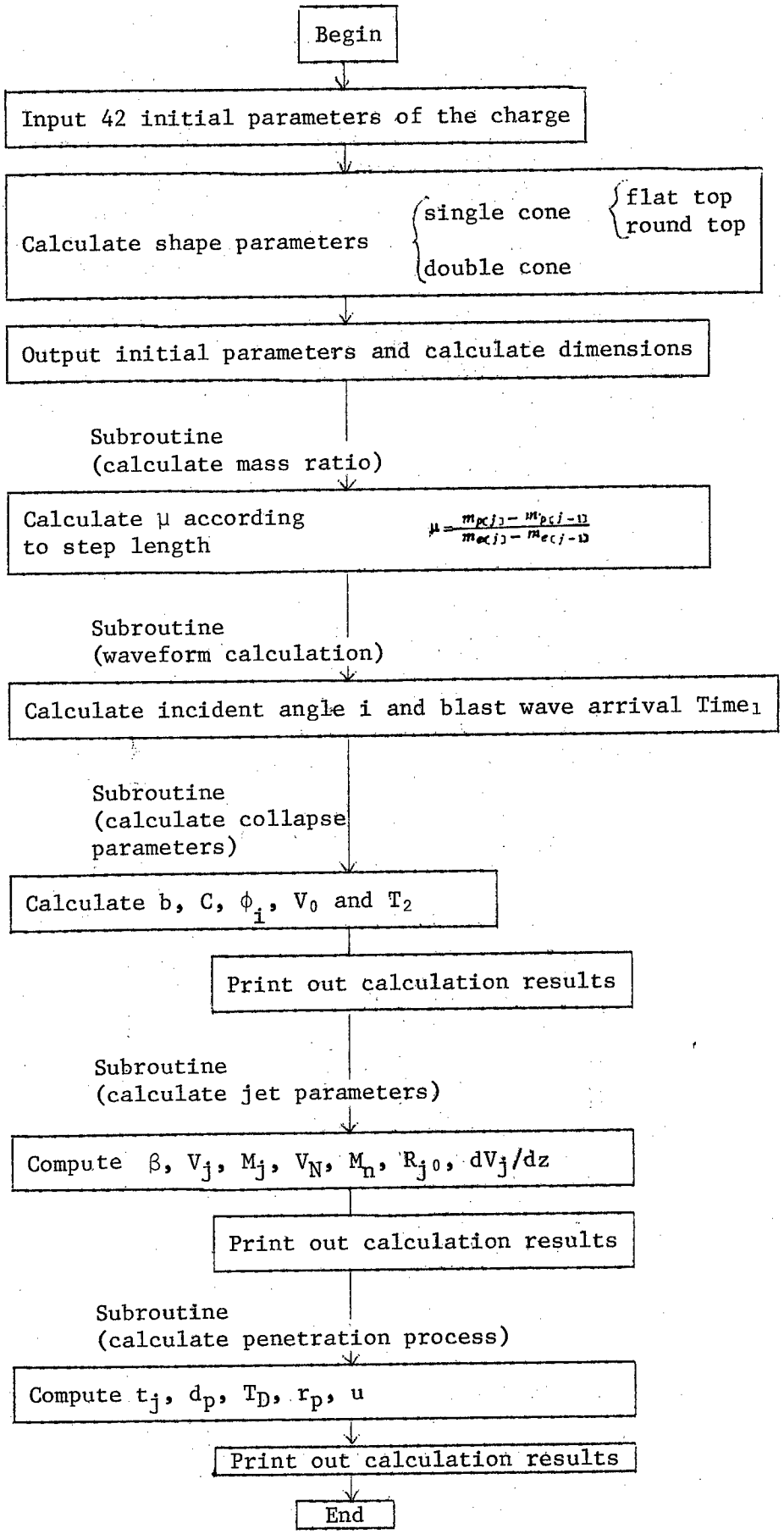

Figure 3.1. Flow Diagram of the Computer Program

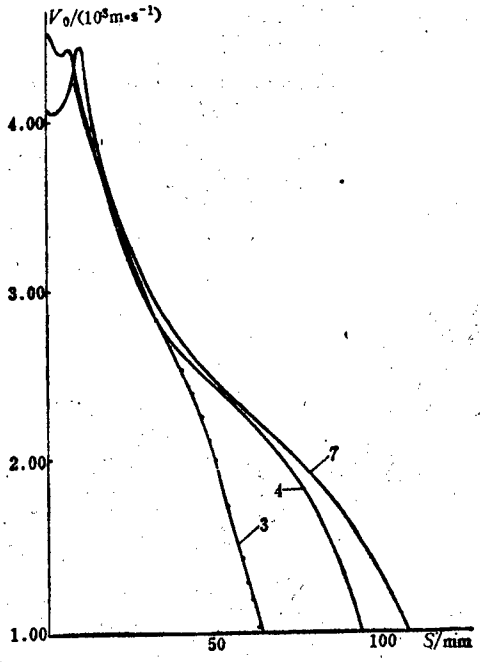

Figure 3.2. Collapse Velocity V_0 Along Curve S (Numbers 3, 4 and 7 represent different charges and dots are the iterated values based on the pestle recovery experiments)

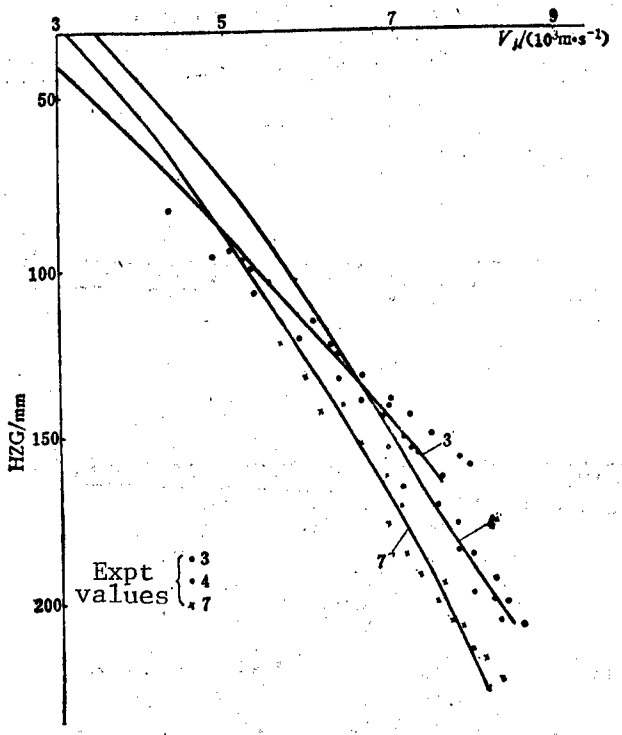

Figure 3.3. Distribution of V_j When the Jet Head Arrives the Explosion Height

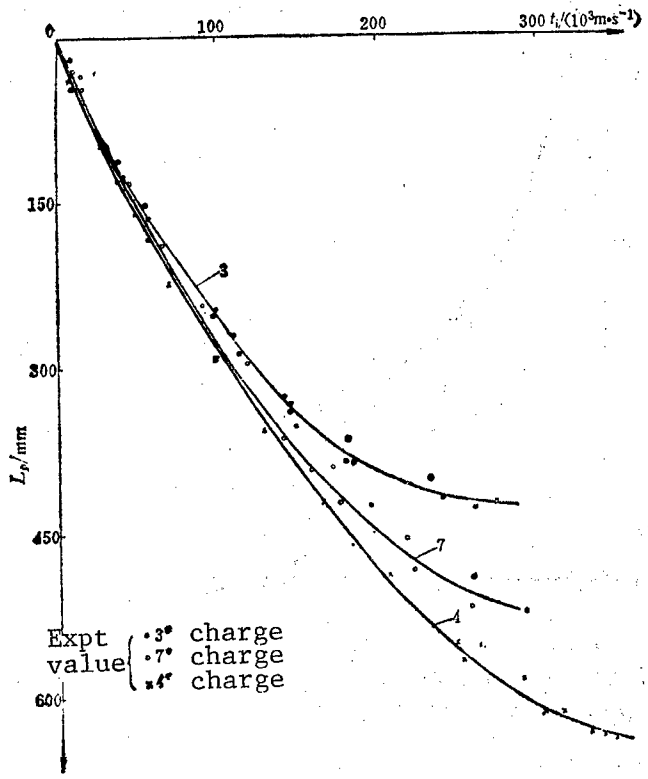

Figure 3.4. L_p Versus t_j in the Penetration Process

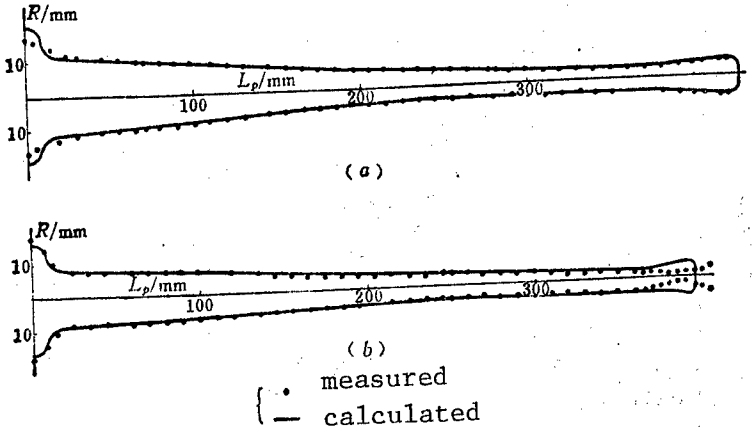

Figure 3.5. Penetration Hole Profile

Key: (a) No 45 steel (b) No 6 steel

(3) The fluid treatment of the jet-target interaction is valid for the early phase of the penetration and the effects of the material strength are important in the late stage of the penetration. The V_j versus u relationship with a strength correction term is generally applicable.

(4) The critical penetration velocity computed using the formula

$$V_{cR} = \sqrt{\sigma b/28}$$

is usually higher than the expected value because the accumulation at the bottom of the hole is serious in the late stage of the penetration. The critical velocity is therefore for the situation where the incoming jet cannot reach the bottom of the hole and the tensile strength of the target material.

(5) In addition to the effects of the material strength in the late stage of the penetration, the break-up of the jet and the jet position are also important. The break-up mechanism is closely related to the liner material and the fabrication method. The time and location of the break-up are completely random and it is entirely possible that the late penetration data taken in the single-shot experiments show substantial scattering.

(6) For most charges with a partition plate [wave shaper], the kinetic energy acquired by the liner is about 13-17 percent of the total energy of the explosive. For charges without a partition, the fraction is about 9 percent. The kinetic energy of the jet is about 90 percent of the kinetic energy of the liner, which is finally dissipated as the damage to the target plate by the jet.

(7) The optimum explosion height is about 3.5-4 times the liner diameter, and a larger value should be used for greater conical angles.

This paper included parts of the experimental results obtained by Liu Beisuo [0491 0554 6956] and Wei Min [3634 3046].

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PLASTIC WAVE THEORY AND APPLICATION TO STUDY OF DYNAMIC PROPERTIES OF LOW ALLOY STRUCTURE STEEL

Beijing LIXUE XUEBAO [ACTA MECHANICA SINICA] in Chinese No 4, 1983 pp 352-364

[Article by Duan Zhuping [3008 4376 1627], Sun Qiqing [1327 3823 3237], and Tian Langqiao [3944 5695 2890], Institute of Mechanics, Chinese Academy of Sciences: "Plastic Wave Theory and Application to the Study of Dynamic Properties of a Low Alloy Structure Steel"]

[Text] Abstract

This article proposes an experimental method of wave propagation to determine dynamic properties of a low alloy structure steel. From the angle of dislocation dynamics a relational constitutive model is proposed to describe the dynamic properties of this kind of steel. This article puts forward a numerical method of solving equations containing a third order dispersion term to compare experimental results and numerical calculations. And it proves that the constitutive model proposed in this article can be used to describe its properties.

During the past 20 years significant advances have been made in plastic dynamics research. There are two basically different but intimately related topics in this area: one is plastic wave theory which attempts to explain the laws of wave propagation in a metal when the magnitude of the wave exceeds the limits of the material's elasticity. The second is research on determining the dynamic properties, especially the constitutive relations, of metals through experimental methods. Although many articles have been written within the framework of unidimensional stress, there are still many basic questions still to be resolved, one of which is how to research the transverse inertia caused by lateral movement. This effect cannot be overlooked, especially at the head of the wave. To be sure, it is very difficult to achieve satisfactory answers to this question. Can we put forward a simple and practical method which can still be processed within the scope of unidimensional theory?

Another important question is how to determine correctly the constitutive model to be adopted in calculations. As Lindholm has pointed out, the wave cross-section is not sensitive to the concrete form of the constitutive model. For this reason one can select one of the above constitutive forms, such as the Malvern model, Gilman model, etc., fitting the computational model and the experimental model together to determine the parameters to be determined in the constitutive model. Thus one can ask the question: Which constitutive model is both simple and rational and what is the smallest number of constitutive parameters necessary to describe the constitutive model of rate dependent matter?

The aim of this article is to study this question through experiment and numerical analysis. The experimental method used in our laboratory is illustrated in Figure 1. Through careful design, a barrel with an internal diameter of 14.9 mm can achieve stable and adjustable projectile velocity. When a projectile made of 18Ni maraging steel and with a length of 300 mm strikes a wave guide shaft at a certain velocity, it produces propagation of a stress wave along the waveguide shaft and generates reflection and transmission at the interface of the test device and the guide shaft. To record the incident and reflection stress pulse, a comma-shaped 2 x 3 mm^2 electrical resistance strain foil was attached on the wave guide shaft 45 mm from the interface of the test device and the guide shaft and 3 to 4 strain foils were attached to the test device each separated from the other by 15 mm. The profile of the plastic wave at the test device and the momentary elastic wave is recorded by two bilinear oscilloscopes and an AD converter. The oscilloscope is triggered by the strain signal given off by the strain foil attached to the wave guide shaft. In this way, four or five strain waves can be obtained in one experiment.

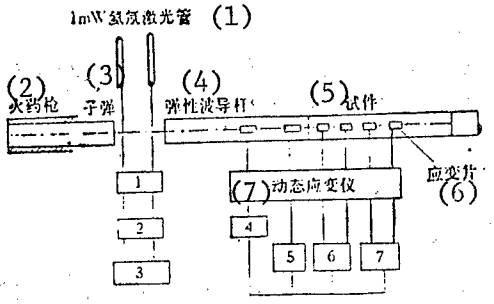


Figure 1. Experimental Device for Measuring Strain-Time Wave Forms [boxed numbers] 1. photodiode 2. amplifier 3. E324 counter 4. trigger circuit 5. AD modulus converter 6,7. bilinear oscilloscope

Key:
(1) 1 mW helium-neon laser
(2) gun
(3) projective
(4) elastic wave guide shaft
(5) test device
(6) strain gauge
(7) dynamic strain meter

The first section of this article is on the plastoelastic shaft's equation of motion derived from Hamilton's principles. In the second section, a general form of the rate dependent constitutive relationship is proposed from the angle of dislocation dynamics. By comparing experiments and numerical results, the following conclusion can be reached: For this type of low alloy structure steel, the characteristic relaxation time, the ratio between the movable dislocation saturation density and the initial dislocation density, and the hardening modulus are the three important physical parameters which control the macroscopic plastic flow of this type of steel. Finally, we discuss in essential terms the numerical differential method used in this article to solve the basic equation.[1,2] A comparison of the difference and the precision shows that the cumulative error in computation does not exceed 1 percent which means that this method can be used to study the dynamic properties of metals under high strain.

I. Derivation of Equation of Motion in View of Transverse Inertia

First of all to derive the equation of motion of a plastoelastic shaft, let u_x and u_r be the axial and radial shift of a cylindrical shaft, x the distance from the cross-section under consideration from the missile and guide shaft interface, and t the time. Then we introduce the following hypotheses;

Hypothesis 1: In the process of changing shape, the transverse cross-section of the shaft maintains the plane without changing, therefore the longitudinal shift u_x and the longitudinal particle velocity v_x and the coordinate r are unrelated, therefore we have

$$u_x = u_x(x,t) \tag{1.1a}$$

$$v_x = \partial u_x/\partial t = v_x(x,t) \tag{1.1b}$$

Hypothesis 2: Compared with stress σ_x, the other stress components under the shaft coordinate system σ_{ij} can be overlooked, therefore we have

$$\sigma_{ij} = \begin{cases} =0 & \text{当 } i,j \neq 1 \\ >0 & \text{当 } i=j=1 \end{cases} \tag{1.2}$$

Hypothesis 3: Strain component is minute, therefore, all strain components can be divided into a combination of elastic part and plastic part, and if ε_r and ε_θ are used to represent transverse and circumferential direction stress, and pressure-[drawing] stress is correct, then we have

$$\varepsilon_x = \varepsilon_x^e + \varepsilon_x^p = -\frac{\partial u_x}{\partial x} \tag{1.3a}$$

$$\varepsilon_r = \varepsilon_r^e + \varepsilon_r^p = -\frac{\partial u_r}{\partial r} \tag{1.3b}$$

$$\varepsilon_\theta = \varepsilon_\theta^e + \varepsilon_\theta^p = -\frac{u_r}{r} \tag{1.3c}$$

and the elastic part of the stress and strain follows Hooke's law. The material is assumed to be homogeneous in all directions, Young's modulus is E, Poisson's ratio is v, then according to hypothesis 2, we obtain the following

$$\varepsilon_x^e = \frac{1}{E}\sigma_x \tag{1.4a}$$

$$\varepsilon_\theta^e = \varepsilon_r^e = -\frac{\nu}{E}\sigma_x \tag{1.4b}$$

Hypothesis 4: The plastic part of body strain is 0, i.e.,

$$\varepsilon_x^p + \varepsilon_r^p + \varepsilon_\theta^p = 0 \tag{1.5}$$

substituting (1.3a-c) for (1.5) and using (1.4a,b) one gets

$$\frac{\partial u_r}{\partial r} + \frac{1}{r}u_r = \varepsilon_x - \frac{1}{E}(1-2\nu)\sigma_x \tag{1.6a}$$

and the symmetry of deformation demands

$$u_r = 0 \qquad (\text{当 } r = 0) \tag{1.6b}$$

thus, integrating (1.6a) we can derive

$$u_r = \frac{1}{2}r\left[\varepsilon_x - \frac{1}{Er^2}2(1-2\nu)\int_0^r r\sigma_x dr\right] \tag{1.7}$$

If the radial shift u_r relies on r only linearly, and σ_x and r are unrelated, therefore we get.

$$u_r = \frac{1}{2}r\left(\varepsilon_x - \frac{1}{E}(1-2\nu)\sigma_x\right) \tag{1.8}$$

then the radial particle velocity v_r and strain ε_r, ε_θ can be represented as

$$v_r = \partial u_r/\partial t = \frac{1}{2}r\left[\frac{\partial \varepsilon_x}{\partial t} - \frac{1}{E}(1-2\nu)\frac{\partial \sigma_x}{\partial t}\right] \tag{1.9}$$

$$\varepsilon_r = \varepsilon_\theta = \frac{1}{2}\left(\varepsilon_x - \frac{1-2\nu}{E}\sigma_x\right) \tag{1.10}$$

Hypothesis 5: Based on Malvern's theory of rate relation, under unidimen-ional sional stress, the plastic strain rate $\dot{\varepsilon}_x^p$ relies only on stress σ_x and plastic strain ε_x^p therefore we have

$$\dot{\varepsilon}_x^p = g(\sigma_x, \varepsilon_x) = g_1(\sigma_x, \varepsilon_x^p) \tag{1.11}$$

which refers to $g(\sigma_x, \varepsilon_x)$ as plastic relaxation coefficient. Linking (1.11) and (1.4) we can derive the constitutive relation

$$\dot{\varepsilon}_x = \frac{1}{E}\dot{\sigma}_x + g(\sigma_x, \varepsilon_x) \tag{1.12}$$

replacing (1.10) with (1.12) we can derive the radial velocity

$$\begin{aligned} v_r &= r\nu\left[\dot{\varepsilon}_x + \left(\frac{1}{2\nu} - 1\right) g(\sigma_x, \varepsilon_x)\right] \\ &= r\nu\left[\dot{\varepsilon}_x^e + \left(\frac{1}{2\nu}\right) g(\sigma_x, \varepsilon_x)\right] \\ &= r\nu\dot{\varepsilon}_x^e + \frac{1}{2} r\dot{\varepsilon}_x^p = r\nu\dot{\varepsilon}_x + \frac{r}{2}(1-2\nu)\dot{\varepsilon}_x^p \end{aligned} \tag{1.13}$$

or
$$r\nu\dot{\varepsilon}_x \leqslant v_r \leqslant \frac{1}{2} r\dot{\varepsilon}_x \tag{1.14}$$

from (1.13) we know that transverse velocity v_r is the union of two terms, the first $r\nu\dot{\varepsilon}_x^e$ is induced by the longitudinal elastic strain rate, and the second $\frac{1}{2}r\dot{\varepsilon}_x^p$ comes from the longitudinal plastic strain rate. Since the value v of the Poisson ration of metals is always less than $\frac{1}{2}$, (1.14) shows that under the same longitudinal strain rate, the radial velocity of the elastoplastic shaft always should be greater than the corresponding radial velocity of the elastic shaft. In this sense, the elastoplastic shaft has a greater transverse inertial effect. To research this effect, the traditional unidirection equation of motion must be revised. Proceeding from the Hamilton principle, Rayleigh first derived the equation of motion of an elastic cylinder, which is[3]

$$\rho\frac{\partial v_x}{\partial t} + \frac{\partial \sigma_x}{\partial x} = \frac{1}{2}\rho\nu^2 a^2 \frac{\partial^3 v_x}{\partial t \partial x^2} \tag{1.15}$$

in which ρ is the density of the elastic shaft, a is the radius of the cylinder. Obviously, the situation for an elastoplastic shaft is much more complex, the transverse inertia not only is related to the geometrical dimensions of the test device, but also relies on the form of the constitutive function. To view it simply, for the time being we assume the following form of the plastic relaxation function

$$g(\sigma_x, \varepsilon_x) = \alpha(\sigma_x - \sigma_s) = \alpha\sigma_s\left(\frac{\sigma_x}{\sigma_s} - 1\right) \tag{1.16a}$$

or

$$\dot{\varepsilon}_x = \frac{1}{E}\dot{\sigma}_x + \alpha(\sigma_x - \sigma_s) \tag{1.16b}$$

Here, d is the characteristic relaxation constant, σs is the static yield stress. According to (1.14), particle radial velocity becomes

$$v_r = -r\nu\frac{\partial^2 u_x}{\partial t \partial x} + \frac{r}{2}\alpha(1-2\nu)(\sigma_x - \sigma_s) \tag{1.17}$$

taking into account a test device with length 1 and radius a, the general kinetic energy it possesses is

$$T = \pi\rho \int_0^l \int_0^a r(v_x^2 + v_r^2) dr dx \tag{1.18}$$

replacing (1.18) with (1.1) and (1.17), and carrying out integration with regard to r, one can derive

$$\begin{aligned} T = {} & \frac{1}{2}\pi\rho a^2 \int_0^l \left(\frac{\partial u_x}{\partial t}\right)^2 dx + \frac{1}{4}\pi\rho\nu^2 a^4 \int_0^l \left(\frac{\partial^2 u_x}{\partial t \partial x}\right)^2 dx \\ & - \frac{1}{4}\pi\rho a^4 \alpha\nu(1-2\nu) \int_0^l (\sigma_x - \sigma_s) \frac{\partial^2 u_x}{\partial t \partial x} dx \\ & + \frac{1}{16}\pi\rho a^4 \alpha^2 (1-2\nu) \int_0^l (\sigma_x - \sigma_s)^2 dx \end{aligned} \tag{1.19}$$

From (1.19) one can see that the general kinetic energy is made up of four elements: the first is caused by longitudinal motion which is an important contribution to kinetic energy. The other three are corrections stimulated by radial motion. If only an elastic deformation occurs, then the latter two terms in (1.19) do not appear. When a plastic deformation occurs, since the magnitude of its order of magnitude is known, the third and fourth terms are identical to the second and thus cannot be overlooked. According to hypothesis 2, the general elasticity stored in the shaft can satisfy

$$U = \frac{1}{2}\int_0^l \int_0^a \sigma_x \varepsilon_x^e 2\pi r dr dx = \frac{1}{E}\pi a^2 \int_0^l \sigma_x^2 dx \tag{1.20}$$

To derive the equation of motion, we use the Hamilton principle

$$\delta \int_{t_0}^t (T - U) dt - \int_{t_0}^t \delta W^p dt = 0 \tag{1.21}$$

in which δW^p is the plastic virtual work $\delta W^p = \pi a^2 \int_0^{\ell} \sigma_x \delta \varepsilon_x^p dx$ which corresponds to the virtual shift δu_x. One can use the shift u_x from (1.16b) to represent the stress σ_x

$$\sigma_x = E \int_0^t e^{\alpha E(\tau - t)} \cdot \left(\alpha\sigma_s - \frac{\partial^2 u_x(x,\tau)}{\partial x \partial \tau}\right) d\tau \tag{1.22a}$$

or the form

$$\delta\sigma_x = -E \int_0^t e^{\alpha E(\tau - t)} \cdot \frac{\partial^2 \delta u_x(x,\tau)}{\partial x \partial \tau} d\tau \tag{1.22b}$$

to show that the variation of stress and the shift variation are not independent. Replacing (1.19) and (1.20) in (1.22a) and (1.22b), according to (1.21)

we can use the customary method to deduce the equation of motion but the operation is pretty complex and to simplify the derivation process, here we give only the final results expressed in the form of nondimensional steel.

$$\frac{\partial \bar{v}_x}{\partial \bar{t}} + \left[1 - \frac{\eta^2}{8}(1-2\nu)\right]\frac{\partial \bar{\sigma}_x}{\partial \bar{x}} = \frac{\nu^2}{2}\frac{\partial^3 \bar{v}_x}{\partial \bar{t}\partial \bar{x}^2} - \frac{\nu}{4}(1-2\nu)\eta^2 \cdot \int_0^t e^{\eta(t-\tau)}\left[\frac{\partial^2 \bar{v}_x}{\partial \bar{x}^2} - \frac{(1-2\nu)\eta}{2\nu}\cdot\frac{\partial \bar{\sigma}_x(\tau, x)}{\partial \bar{x}}\right]d\tau \tag{1.23}$$

in which the notation $(\bar{\ })$ means the nondimensional form of the physical quantity in parenthesis, the notation for nondimensional steel is

$$\bar{x} = \frac{x}{a},\quad \bar{t} = \frac{ct}{a},\quad \eta = \frac{Ea\alpha}{c}$$
$$\bar{v}_x = \frac{v_x}{v_s},\quad \bar{\sigma}_x = \frac{\sigma_x}{\sigma_s},\quad \bar{\varepsilon}_x = \frac{\varepsilon_x}{\varepsilon_s} \tag{1.24}$$

Here, a is the radius of the columnar shaft, $c = \sqrt{E/\rho}$ is the elastic wave velocity, ρ is the material density, σ_s, V_s, ε_s are the static yield stress, yield velocity, and yield strain of the material respectively, η is the nondimensional parameter which controls the macroscopic plastic flow. From (1.23) it can be seen that the equation of motion after revision is still fairly complex. If the rightmost element in (1.23) is caused by elastic lateral motion, the second is an integral fraction, caused by plastic lateral motion. If we further assume that the material also satisfies the elastic incompressibility, then (1.23) can be simplified to

$$\frac{\partial \bar{v}_x}{\partial \bar{t}} + \frac{\partial \bar{\sigma}_x}{\partial \bar{x}} = \frac{1}{8}\frac{\partial^3 \bar{v}_x}{\partial \bar{t}\partial \bar{x}^2} \tag{1.25}$$

It should be pointed out that when $v = \frac{1}{2}$, correction of the transverse inertia effect can reach the maximum. To simplify the question, from (1.14) it is clear that if a further regulatory parameter v^* is introduced, assuming the equation of motion adopts the following form:

$$\frac{\partial \bar{v}_x}{\partial \bar{t}} + \frac{\partial \bar{\sigma}_x}{\partial \bar{x}} = \frac{1}{2}v^{*2}\frac{\partial^3 \bar{v}_x}{\partial \bar{t}\partial \bar{x}^2} \tag{1.26}$$

To estimate the influence of lateral motion in numerical calculations, the value of v^* is regulated within the scope of the true Poisson ratio v and $\frac{1}{2}$.

II. Determination of the Plastic Relaxation Function $g(\sigma_x, \varepsilon_x)$

Although the theory of unrelated strain rate first established by von Karaman, G.I. Taylor and Rakhmatulin can explain some characteristics of plastic wave cross-sections derived from measures, many experiments in plastic waves show that the rate dependent relationship theory for describing the dynamic properties of a great many metals is even more rational. The key question is establishing the definition of plastic relaxation function on a more rational

foundation. Of course, at present we cannot rely only on microscopic methods to derive the concrete form of $g(\sigma_x, \varepsilon_x)$. The hypothesis that dislocation movement is brought about on the basis of plastic fluid motion points out that the specific form of various forms of $g(\sigma_x, \varepsilon_x)$, in particular it was J.W. Taylor who first used dislocation dynamics to successfully explain the decay of elastic advance wave which occurs in plate impact experiments, and there have been great advances in this work over the past 20 years.[4-9] Dislocation theory hypothesizes that through the Orowan formula the plastic force function $g(\sigma_x, \varepsilon_x)$ can give

$$\dot{\varepsilon}_x^p = g(\sigma_x, \varepsilon_x) = \frac{4}{3}\phi b N \bar{v}_d \tag{2.1}$$

in which ϕ is the orientation factor, b is the Burgers vector, N is the movable dislocation density on the slip surface, $\bar{v}_d$ is the average velocity of the dislocation. Our key is to define the N and $\bar{v}_d$ as ε_x^p and the function of hyperstress $(\sigma_x - \sigma_s)$. First of all we define N as the function of plastic strain ε_x^p. From revelations obtained in experiments on LiF crystals, Gilman hypothesized[10] that the slip zone in crystals can be divided into two stages: the first stage, the dislocation rate of increase $\frac{dN}{dt}$ and the movable dislocation number N are in direct ratio, thus we have

$$\frac{dN}{dt} = \tilde{\alpha} N \tag{2.2}$$

in which $\tilde{\alpha}$ is the increase coefficient. Thus, in the initial stage, the index of dislocation with the time increases; in the second stage, expansion of the dislocation ring and cross completion cause the dislocation to proliferate and once new dislocation rings have proliferated fully, they collide with each other. The result is that either the dislocation is annihilated, or it is locked inside the crystal, and the rate of collisions of two dislocations and the square of the dislocation number are in direct proportion. For this reason, the rate of change of movable dislocation density is

$$\frac{dN}{dt} = \tilde{\alpha} N - \tilde{\beta} N^2 \tag{2.3}$$

in which $\tilde{\beta}$ is the annihilation coefficient, when $N = \tilde{\alpha}/\tilde{\beta}$, the rate of proliferation $dN/dt = 0$. The value at this time is called the saturation density and is expressed as N_m. By the Frank-Read source mechanism, if ℓ_d expresses the distance between dislocation nodes or obstacles, then the proliferation coefficient $\tilde{\alpha}$ is nearly equal to v_d/ℓ_d, and a single dislocation in a unit of time scanned surface is equal to bv_d, as illustrated in Figure 2. Thus, the total number of collisions per unit time of contrary dislocation is equal to $\frac{1}{2}b\bar{v}_d N^2$ therefore formula (2.3) becomes

$$\frac{dN}{dt} = \tilde{\alpha} N + \tilde{\beta} N^2 = \frac{\bar{v}_d}{l_d} N - \frac{1}{2} b \bar{v}_d N^2 \tag{2.4}$$

Formula (2.4) shows that the proliferation rate of dislocation is in direct proportion to the average dislocation velocity $\bar{v}_d$. Linking (2.1) and (2.2) we get

$$\frac{dN}{d\varepsilon_x^p} = k(N_m - N) \tag{2.5a}$$

$$N|_{\varepsilon_x^p=0} = N_0 \tag{2.5b}$$

in which $k = \frac{3}{8}\phi$ is a constant related to the orientation factors, N_0 is the initial movable dislocation density and integrating (2.5) we get

$$N = N_m[1 - (1 - N_0/N_m)e^{-k\varepsilon_x^p}] \tag{2.6}$$

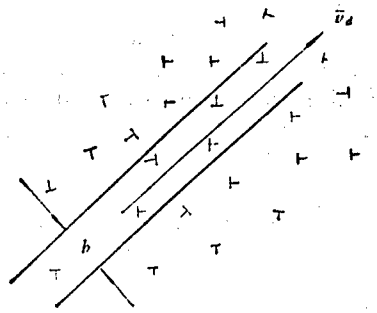


Figure 2. Movement of Dislocation

This dislocation proliferation formula is slightly different from the formula given by Gilman.[6] Gilman's experimental formula is

$$N = (N_0 + M^*\varepsilon_x^p)e^{-H\varepsilon_x^p/\sigma_x} \tag{2.7}$$

in which H is the hardening constant of dislocation proliferation, but in terms of micro strain, giving the first approximation time (2.6) and (2.7) a similar form of expression:

$$N = N_0(1 + M\varepsilon_x^p) \tag{2.8}$$

in which

$$M = \begin{cases} k\left(\frac{N_m}{N_0} - 1\right) \\ M^*/N_0 \end{cases}$$

M expresses the linear proliferation coefficient, (2.8) expresses that dislocation density linearity depends on ε_x^p. This conforms to the experimental observations of Doner et al.[11]

Before we discuss the kinetic condition of dislocation and its average velocity $\bar{v}_d$. Different mechanisms for controlling dislocation motion at

different degrees of stress as has already been discussed in detail in Clifton's article. The motion of dislocation is primarily controlled by two different mechanisms: when the stress and the rate of strain are relatively low, hot activation plays a leading role; when the stress and rate of strain are relatively high, linear and nonlinear damping mechanism play a leading role. Linking these two mechanisms together, Clifton[12] gave a detailed account of the relationship of average velocity $\bar{v}_d$ and stress σ_x. But up until now, in terms of alloy structure steel with high strength, no useful experimental data has been provided, thus we can only rely on the facts of one such experiment: in shock experiments on a long shaft, there is a critical shock velocity v_{cr}, which when lower than v_{cr} shock time does not cause plastic deformation, but the value of v_{cr} increases as ε_x^p increases, thus we can hypothesize that $\bar{v}_d$ is the factor of hyper stress $(\sigma_x - \sigma_s)$ and plastic strains ε_x^p, thus we have

$$\bar{v}_d = f(\sigma_x - \sigma_s, \varepsilon_x^p)$$

expanded it in Taylor series, we get

$$\bar{v}_d = f((\sigma_x - \sigma_s), \varepsilon_x^p) = \sum_{m,n} A_{mn}(\sigma_x - \sigma_s)^m(\varepsilon_x^p)^n \tag{2.9}$$

in which A_{mn} is the damping coefficient controlling dislocation motion, and clearly $A_{00} = 0$, $a_{10} > 0$, and $A_{01} < 0$. If all coefficients but A_{10} were equal to zero, then (2.9) gives the linear viscid damping model from Greenman.[12] Substituting (2.9) and (2.6) in (2.1), we get a general form of the plastic relaxation factor

$$\dot{\varepsilon}_x^p = g(\sigma_x, \varepsilon_x) = K_0\left[1 - \left(1 - \frac{N_0}{N_m}\right)e^{-k\varepsilon_x^p}\right]\sum_{m,n} A'_{mn}\left(\frac{\sigma_x}{\sigma_s} - 1\right)^m(\varepsilon_x^p)^n \tag{2.10}$$

in which $K_0 = \frac{4}{3}\phi b N_m A_{10} \cdot \sigma_s$ is a characteristic relaxation constant which has stress rate dimensions, A'_{mn}/A_{10} is the nondimensional damping coefficient. If we take a first approximation in (2.6) and (2.9), then (2.10) can become:

$$\dot{\varepsilon}_x^p = K[1 + M\varepsilon_x^p]\left[\frac{\sigma_x}{\sigma_s} - 1 - H\varepsilon_x^p\right] \tag{2.11a}$$

or

$$\dot{\varepsilon}_x = \frac{1}{E}\dot{\sigma}_x + K(1 + M\varepsilon_x^p)\left(\frac{\sigma_x}{\sigma_s} - 1 - H\varepsilon_x^p\right) \tag{2.11b}$$

in which $K = \frac{N_0}{N_m}$ and M and H are the three microscopic parameters which controls macroscopic plastic flow, and according to (1.24), after nondimensionalizing (2.11b) we get

$$\frac{\partial\bar{\varepsilon}_x}{\partial\bar{t}} = \frac{\partial\bar{\sigma}_x}{\partial\bar{t}} + \bar{K}(1 + \bar{M}\bar{\varepsilon}_x^p)(\bar{\sigma}_x - 1 - \bar{H}\bar{\varepsilon}_x^p) \tag{2.11c}$$

in which the nondimensional parameters $\bar{K} = aK/v_s$, $\bar{M} = M\varepsilon_s$, and $\bar{H} = H\varepsilon_s$ must be selected appropriately to cause the numerical results and the experimental results to fit. Obviously, in our problem, there are two characteristic times: τ and τ_2, in which $\tau_1 = a_2/c_2$ is determined by the radius of the cylinder, τ_2 is the characteristic relaxation time of plastic flow. The nondimensional parameter $\bar{K}$ is the ratio of τ_1 and τ_2, i.e.,

$$\bar{K} = \tau_1/\tau_2 = \left(\frac{3}{4}\phi a_2 \Big/ \frac{1}{bN_0}\right) \cdot \frac{v_d^*}{v_s} \tag{2.12}$$

in which a_2 is the test device radius, v_d^* is a characteristic velocity of dislocation. It expresses the average velocity of dislocation when the functional stress σ_x reaches three times σ_s. In fact, the constant $\bar{K}$ plays an important role in controlling plastic flow. In the example of Armco iron, according to the data given by Curran,[13] we have

$$\left.\begin{aligned} &\frac{v_d^*}{v_s} \sim \frac{b\rho_2 c_2}{B_d} \\ &b = 2.5 \times 10^{-8}\text{cm}^2, N_0 = 2 \times 10^8\text{cm}^2 \end{aligned}\right\} \tag{2.13}$$

in which $\rho_2 c_2$ is the elastic acoustic resistance of the projectile, B_d is the viscid damping coefficient, which is approximately equal to 0.1 (dynes·sec/cm^2). From (3.13) and (3.14) we know that when $a_2 = 0.75$ cm^3, $c = 7.8$ g/cm^3, $c = 5.0 \times 10^3$ m/s, the value of $\bar{K}$ is approximately 2.80. Similarly, according to Jones and Mote's data on monocrystalline copper[14]: $B_d = 7 \times 10^{-7}$ (kbar-μs), $\rho = 8.9$ g/cm^3, $c = 3.9 \times 10^3$ m/s, thus the $\bar{K}$ value of monocrystalline copper is 1.58.

III. Comparison of Experiment and Numerical Analysis Results

Above we have already derived the basic equations controlling elastic guide shaft, projectile, and test device wave propagation. They were given in nondimensional form.

For the elastic shaft (projectile and wave guide shaft), there are the following groups of equations: (for ease of reading, we have dropped the symbol "–" which expresses nondimensionalization):

$$\begin{cases} \rho_1 \dfrac{\partial v_{x1}}{\partial t} + \dfrac{\partial \sigma_{x1}}{\partial x} = \dfrac{1}{2}\rho_1 v_1^2 \dfrac{\partial^3 v_{x1}}{\partial t \partial x^2} & 0 \leqslant x \leqslant l_p + l_g \quad (3.1a) \\ \dfrac{\partial v_{x1}}{\partial x} + \dfrac{\partial \varepsilon_{x1}}{\partial t} = 0 & 0 \leqslant x \leqslant l_p + l_g \quad (3.1b) \\ \dfrac{\partial \varepsilon_{x1}}{\partial t} = E_1 \dfrac{\partial \sigma_{x1}}{\partial t} & 0 \leqslant x \leqslant l_p + l_g \quad (3.1c) \end{cases}$$

The subscript 1 here corresponds to the elastic shaft, ρ, is the ratio of the density of the elastic guide shaft and the test device, i.e., $\rho_1 = \rho_{\text{elastic}}/\rho_{\text{test}}$ and $l_p = l_p/a$, $l_g = l_g/a$ are the nondimensional length of the projectile and the guide shaft. See Figure 11.

The control equation group for the plastic test device is as follows (the symbol "-" which expresses nondimensionalization has similarly been dropped):

$$\begin{cases} \dfrac{\partial v_{x2}}{\partial t} + \dfrac{\partial \sigma_{x2}}{\partial x} = \dfrac{1}{2}\nu_2^2 \dfrac{\partial^3 v_{x2}}{\partial t \partial x^2} & (3.2a) \\ \dfrac{\partial v_{x2}}{\partial x} + \dfrac{\partial \varepsilon_{x2}}{\partial t} = 0 & (3.2b) \\ \dfrac{\partial \varepsilon_{x2}}{\partial t} = \dfrac{\partial \sigma_{x2}}{\partial t} + K(1 + M\varepsilon_{x2}^p)(\sigma_{x2} - 1 - H\varepsilon_{x2}^p) & (3.2c) \end{cases}$$

in which the subscript 2 corresponds to the plastic test device, if the radius of the guide shaft and test device shaft are both a, to simultaneously solve (3.1a-c) and (3.2a-c) it is necessary to give initial conditions and boundary conditions, thus we have

initial conditions

$$v_x = \begin{cases} v_p & t = 0,\ 0 \leqslant x \leqslant l_p \\ 0 & t = 0,\ l_p \leqslant x \leqslant l_p + l_g \end{cases} \quad (3.3a)$$

$$\sigma_{x1} = \sigma_{x2} = \varepsilon_{x1} = \varepsilon_{x2} = 0 \quad t = 0,\ 0 \leqslant x \leqslant l_p + l_g + l_s \quad (3.3b)$$

boundary conditions

$$\sigma_{x1} = \sigma_{x2}\ v_{x1} = v_{x2} \quad x = l_p + l_g \quad (3.3c)$$

$$\sigma_{x1} = 0 \quad x = 0 \quad (3.3d)$$

$$\sigma_{x2} = 0 \quad x = l_p + l_g + l_s \quad (3.3e)$$

To verify whether the constitutive equation (2.11b) given in this article can be used to describe the dynamic properties of alloy steel with high strength, reference 15 gives the relevant theoretical analysis and method of solving perturbation. Here we will solve the group of equations described above and rationally select the physical parameters K, M, and H so we can make the results of the calculations conform to the experimental wave forms.

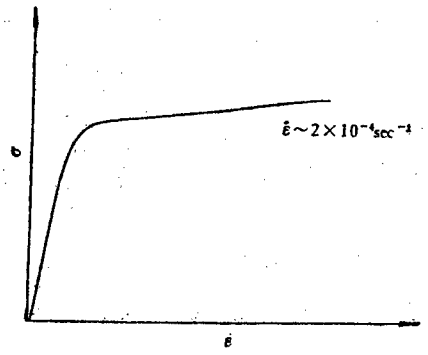
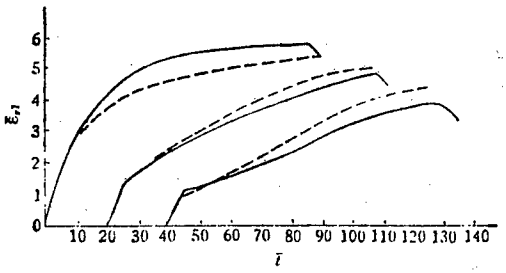


Figure 3. Low Alloy Structure Steel Static Stretch Stress-strain Curve

A simple stretch test on this kind of low alloy structure steel under low rate of strain ($\dot{\varepsilon} < 2 \times 10^{-4} x^{-1}$) was carried out on an Instron test machine. See Figure 3 for the static stress and strain curve, which can be expressed more rationally using a four part linear hardening curve:

(3.4)

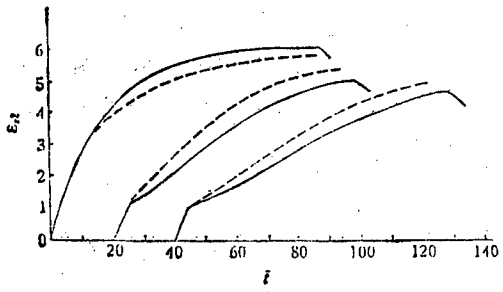
The test device and guide shaft material constant and the test device's hardening modulus H_i, σ_i, ε_i respectively, were given by the experiment. The typical recording of the strain-time wave forms which we obtained at different cross-sections of the test device in the dynamic properties test can be seen in Photograph 1 (Plate I). A comparison of the results of calculations according to the theoretical model and the experimental results of nondimensional strain-time wave forms of longitudinal waves in this low alloy structure steel at different shock velocities are shown in Figures 4-8.



(a) (b)

$\bar{v}_p = 2.60$ ——实验 ----计算

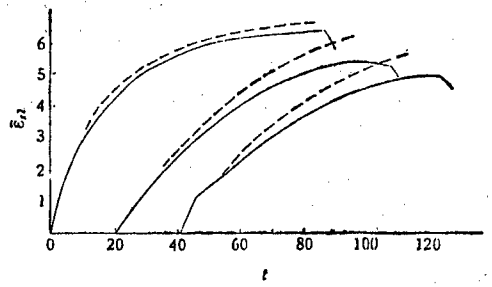
Figure 4



(a) (b)

$\bar{v}_p = 2.70$ ——实验 ----计算

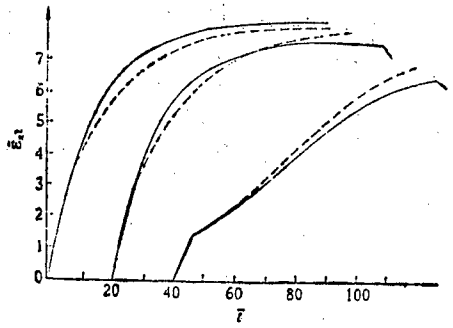
Figure 5



(a) (b)

$\bar{v}_p = 2.80$ ——实验 ----计算

Figure 6



(a) (b)

$\bar{v}_p = 3.00$ ——实验 ----计算

Figure 7

Key: a. experiment b. calculation

The wave forms obtained in the experiments show that the magnitude of the elastic advance wave decreases with propagation distance and that there is no so-called residual strain platform as was indicated by the theory of strain rate independence. The distribution curve of the typical residual strain of the test device in the experiment according to the length of the test device shaft is illustrated in Figure 9.

$$\rho_i \frac{v_k^{n+1} - v_k^n}{\Delta t} + \frac{\sigma_{k+\frac{1}{2}}^{n+\frac{1}{2}} - \sigma_{k-\frac{1}{2}}^{n+\frac{1}{2}}}{\Delta x}$$

$$= \frac{\beta_i}{\Delta t \cdot (\Delta x)^2} \cdot \left[(v_{k+1}^{n+1} - 2v_k^{n+1} + v_{k-1}^{n-1}) - (v_{k+1}^n - 2v_k^n + v_{k-1}^n) \right]$$

$$+ \frac{\sqrt{E_i}}{2\Delta x} (v_{k+1}^n - 2v_k^n + v_{k-1}^n) \cdot S \qquad (3.5a)$$

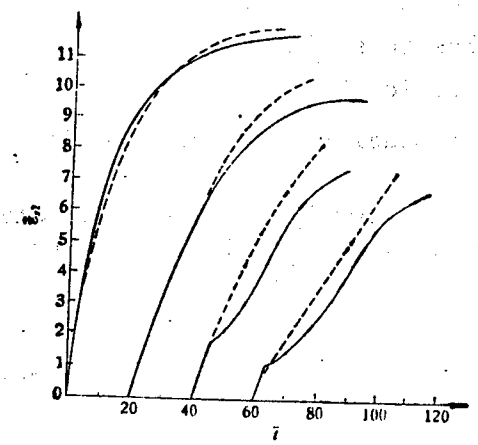


Figure 8.

Key: a. experiment
b. calculation

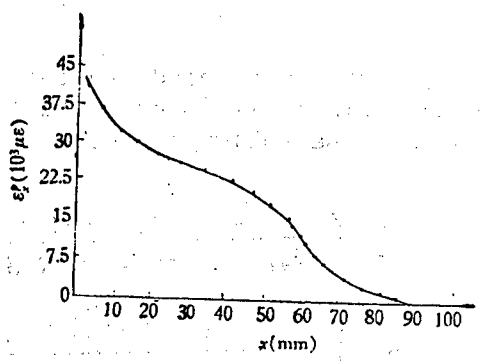


Figure 9. Distribution Curve of Experimental Measuring Points of Residual Changes With Shaft Length at Shock Velocity

v_p = 3.51 (nondimensional)

In numerical solution results of calculation and the wave forms of the experiments, we used addition variable factor tetragonal network method[11] as illustrated in Figure 10. Calculating the solution of time t from the solution of time t - $\Delta\tau$. The equation group (3.1a-c) and (3.2a-c) can be expressed as the following difference equation in unified form (for ease of writing we have eliminated the subscript x on σ_x and v_x):

$$\frac{\varepsilon_{k+\frac{1}{2}}^{n+\frac{3}{2}} - \varepsilon_{k+\frac{1}{2}}^{n+\frac{1}{2}}}{\Delta t} + \frac{v_{k+1}^{n+1} - v_k^n}{\Delta x} = \frac{\sqrt{E_i}}{2\Delta x}(\sigma_{k+\frac{3}{2}}^{n+\frac{1}{2}} - 2\sigma_{k+\frac{1}{2}}^{n+\frac{1}{2}} + \sigma_{k-\frac{1}{2}}^{n+\frac{1}{2}}) \cdot R \tag{3.5b}$$

$$\frac{1}{E_i}\frac{\sigma_{k+\frac{1}{2}}^{n+\frac{3}{2}} - \sigma_{k+\frac{1}{2}}^{n+\frac{1}{2}}}{\Delta t} + \frac{v_{k+1}^{n-1} - v_k^{n-1}}{\Delta x} + g_i\left(\frac{\sigma_{k+\frac{1}{2}}^{n+\frac{3}{2}} + \sigma_{k+\frac{1}{2}}^{n+\frac{1}{2}}}{2}, \frac{\varepsilon_{k+\frac{1}{2}}^{n+\frac{3}{2}} + \varepsilon_{k+\frac{1}{2}}^{n+\frac{1}{2}}}{2}\right)$$

$$= \frac{1}{2\Delta x}(\sigma_{k+\frac{3}{2}}^{n+\frac{1}{2}} - 2\sigma_{k+\frac{1}{2}}^{n+\frac{1}{2}} + \sigma_{k-\frac{1}{2}}^{n+\frac{1}{2}}) \cdot R \tag{3.5c}$$

in which

$$\rho_i = \begin{cases} \rho_1/\rho_2 & i = 1 \text{ (corresponding to elastic shaft)} \\ 1 & i = 2 \text{ (corresponding to elastic shaft)} \end{cases}$$

$$\beta_i = \begin{cases} 0.042 & i = 1 \text{ (corresponding to elastic shaft)} \\ 0.0125 & i = 2 \text{ (corresponding to elastic shaft)} \end{cases}$$

$$E_i = \begin{cases} E_1/E_2 & i = 1 \text{ (corresponding to elastic shaft)} \\ 1 & i = 2 \text{ (corresponding to elastic shaft)} \end{cases}$$

$$g_i = \begin{cases} 0 & i = 1 \text{ (corresponding to elastic shaft)} \\ K(1 + M\varepsilon^p)(\sigma - 1 - H\varepsilon^p) & i = 2 \text{ (corresponding to elastic shaft)} \end{cases}$$

$\Delta\tau$ and Δ_x represented nondimensional time and space step length, respectively, stress and strain are taken in half step length positions, variable factors S and R take the following form:

$$S = \left(\frac{|v_{k+1}^n - 2v_k^n + v_{k-1}^n|}{|v_{k+1}^n - v_k^n| + |v_k^n - v_{k-1}^n| + \delta}\right)^3 \tag{3.6a}$$

$$R = \left(\frac{|\sigma_{k+\frac{3}{2}}^{n+\frac{1}{2}} - 2\sigma_{k+\frac{1}{2}}^{n+\frac{1}{2}} + \sigma_{k-\frac{1}{2}}^{n+\frac{1}{2}}|}{\left|\sigma_{k+\frac{3}{2}}^{n+\frac{1}{2}} - \sigma_{k+\frac{1}{2}}^{n+\frac{1}{2}}\right| + \left|\sigma_{k+\frac{1}{2}}^{n+\frac{1}{2}} - \sigma_{k-\frac{1}{2}}^{n+\frac{1}{2}}\right| + \delta}\right)^3 \tag{3.6b}$$

Here, δ is a very small positive number, the initial condition and boundary condition of the problem can take the place of the following difference format:

$$v_k^0 = \begin{cases} v_p & k = 0,1,2,\cdots,J-1 \\ 0 & k = J, J+1,\cdots,M,M+1,\cdots,N,N+1 \end{cases} \tag{3.7}$$

$$\sigma_k^{\frac{1}{2}} = \varepsilon_k^{\frac{1}{2}} = 0 \quad k = 0,1,2,\cdots,N+1, \tag{3.8}$$

$$\varepsilon_{N+1}^{n+\frac{1}{2}} = \sigma_{N+1}^{n+\frac{1}{2}} = 0, \; v_0^n = v_1^n, \; v_{N+1}^n = v_N^n \tag{3.9}$$

Here, the projectile and the guide shaft are divided into (J + 1) and (M - J - 1) cells, the test device divided into (N - M) cells. Using the triple

diagonal pursuit method from the velocity v_k^n of $t = n \cdot \Delta t$ time one can find v_k^{n+1} of velocity in $t = (n+1)\ \Delta t$ time in the difference equations (3.4a-c) and substitute V_k^{n+1} in (3.5b), then using stress $\sigma_k^{n+1/2}$ and strain $\varepsilon_{k+1/2}^{h+1/2}$, one can find stress and strain $\sigma_k^{n+3/2}$, $\varepsilon_{k+1/2}^{n+3/2}$ in $t = (n + 3/2) \cdot \Delta\tau$ time. To insure sufficient precision, after solving for stress, it is still necessary to substitute it once more using equation (3.5c). Because the grid points are very regular, the initial and boundary conditions (3.7-3.9) are very simple and neat so that calculations can be sufficiently precise and rapid. Taking $\Delta\tau = 0.10$ and $\Delta x = 0.20$ and comparing the difference to the precision, the average maximum error does not exceed 1 percent, as illustrated in Table 3, this proves that this method is sufficiently precise.

The numerical results and the strain-time wave form obtained from experiments corresponding to 5 different shock velocities (nondimensional) $\bar{v}_p$ of 3.51, 3.00, 2.80, 2.70, and 2.60, respectively, are given in comparative form in Figures 4-8. Here the physical parameters accepted are $K = 2.50$, $H = 0.013$, and $M = 0.05$ (nondimensional). From the figures it can be seen that although there is still a slight discrepancy between the strain wave forms obtained from measurement and the results obtained through calculation, they still conform to each other fairly well. As to the wave form closest to the end of the test device, the greatest relative difference between the two results is 10-15 percent. There are primarily two reasons for this: one is the error introduced by using a linear damping model to describe the velocity of dislocation motion, in the actual crystal, dislocation damping is somewhat greater; the other is that there is a certain dispersion of the dynamic sensitivity coefficient of the foil strain gauge used in the experiment, especially in large dynamic plastic deformation. It should be pointed out that the physical parameter $K = 2.50$ is very close to the 2.80 value obtained for the Armco iron estimate in the preceding section; the definition of M may be obtained through microscopic methods, as provided in reference[12]; the value 0.013 for the hardening index H is also close to the 0.016 average value of the data from the experiment. This shows that for low alloy structure steel, the definition of microscopic parameters K, M, and H in the constitutive equation has a definite physical basis. Whether or not this constitutive mode can be extended to other alloys and metals still requires further experimental proof.

This topic was put forward by industrial departments and was completed in August 1980 under the guidance and interest of Professor Zheng Zhemin [6774 0772 2404]. In the experiment process, Comrades Lu Deye [0712 1795 2814] and others gave valuable support and assistance and supplied the test devices necessary for the experiments. In the experiment process, Institute No 52 gave valuable support and assistance. Comrades Zhao Shuanglu [6392 7175 4389] and Yang Yemin [2799 2814 2404] help resolve some measurement technology problems encountered in the experiments. The numerical method in the report was taken from the results of Comrades Wang Lier [3769 0622 1422] and others. Here, we would like to express our heartfelt thanks for their guidance and help.

Figures 4-8 are comparisons of the results of calculations on a theoretical model and the experimental results of longitudinal nondimensional strain-time wave forms in low alloy structure steel under different impact velocities.

Table 3. Comparison of Difference and Precision

(1) 时间 / (2) 解 / 应力 (3)	$\bar{t}=5$		$\bar{t}=10$		$\bar{t}=15$		$\bar{t}=20$		(6) 平均误差
	(4) 精确解	(5) 差分解	(4) 精确解	(5) 差分解	(4) 精确解	(5) 差分解	(4) 精确解	(5) 差分解	
$\bar{\sigma}_{x_2}\|\bar{x}=l_1$	1.4766	1.4707	1.3474	1.3455	1.2409	1.2836	1.2233	1.2461	1.4%
$\bar{\sigma}_{x_2}\|\bar{x}=l_1+2$	1.3426	1.3264	1.2897	1.2833	1.2526	1.2501	1.2264	1.2236	0.56%
$\bar{\sigma}_{x_2}\|\bar{x}=l_1+4$	1.1620	1.1672	1.1998	1.1910	1.1965	1.1915	1.1871	1.1838	0.80%
$\bar{\sigma}_{x_2}\|\bar{x}=l_1+6$	0.0000	0.0271	1.1090	1.1011	1.1331	1.1331	1.1399	1.1358	0.46%

Key:
(1) time
(2) solving for stress
(3) stress
(4) precision
(5) difference
(6) average maximum error

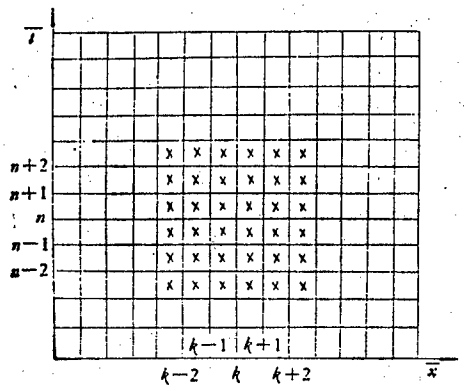


Figure 10. Diagram of Difference Format Used in Calculations

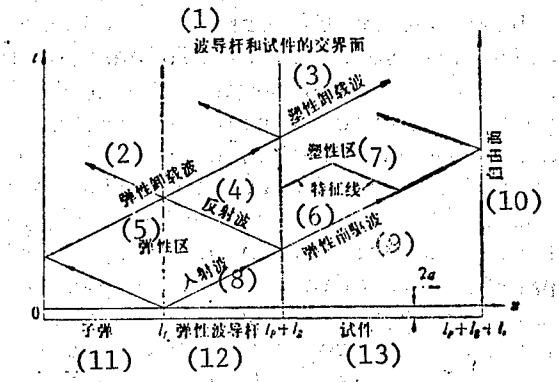


Figure 11. Diagram of Wave in Plastic Shaft and in Test Device and Characteristic Linear Propagation

Key:
(1) wave guide shaft and test device interface
(2) elastic unload wave
(3) plastic unload wave
(4) reflection wave
(5) plastic area
(6) characteristic line
(7) elastic area
(8) incidence wave
(9) elastic advance wave
(10) free face
(11) projectile
(12) elastic wave guide shaft
(13) test device

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PENETRATION CALCULATION OF BROKEN JETS

Beijing BINGGONG XUEBAO [ACTA ARMAMENTARII] in Chinese No 2, May 83 pp 46-54

[Article by Yun Shourong [1926 1108 2837] and Gao Fengxia [7559 7364 7209]]

[Text] I. The Breakup Time and Breakup Position of Broken Jets

The penetration ability of a jet is largely determined by its state (continuous or broken). In penetration calculations, it is generally assumed that the penetration residual jet is broken simultaneously at a particular instant,[1,2] but in reality this is not true; the jet is broken gradually over a finite time interval. Thus, to improve the accuracy of calculation, one must consider the situation where the breakup occurs at different times. The phenomenon of jet breakup is highly complicated and depends on many factors. Currently, there is no theoretical formula capable of predicting the actual breakup position; it can only be determined experimentally.

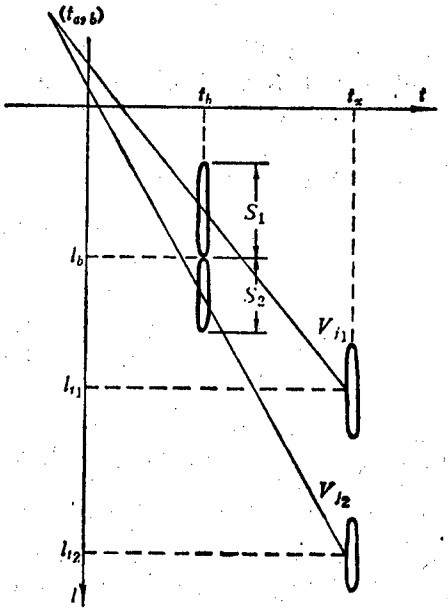

Figure 1. Broken Jet Calculation

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A method of determining the breakup position based on flash radiograph of broken jets has been proposed by Zhou Peiji. We have made improvements to his method to arrive at a more convenient and simpler formula by making the following assumptions:

1. The jet contraction process is neglected; a continuous jet breaks up instantly when it is extended to the breakup point.

2. The velocity distribution remains unchanged before and after the breakup.

3. After breakup, the length and velocity of each micro-segment no longer change.

By neglecting the process of contraction, the continuous jet is assumed to undergo elongation until it reaches the breakup point, at which time it breaks up instantly and the elongation process stops. For illustration let us examine the micro-segments 1 and 2, as shown in Figure 1. The lengths of the micro-segments are S_1 and S_2 and their velocities are V_{j1} and V_{j2}, respectively. At time t_x, the mid points of the segments are located at ℓ_{t1} and ℓ_{t2}; the breakup point of the two segments is at (t_b, ℓ_b). The trajectory of the lower part of segment 1 is

$$V_{j_1}(t-t_a)=l-b-\frac{1}{2}S_1 \tag{1}$$

where (t_a, b) is the coordinate of the virtual origin of the jet. The trajectory of the top part of segment 2 is

$$V_{j_2}(t-t_a)=l-b+\frac{1}{2}S_2 \tag{2}$$

The intersection of equation (1) and equation (2) is the breakup point between the two micro-segments.

$$t_b=\frac{S_1+S_2}{2(V_{j_2}-V_{j_1})}+t_a \tag{3}$$

$$l_b=\frac{S_1V_{j_2}+S_2V_{j_1}}{2(V_{j_2}-V_{j_1})}+b \tag{4}$$

But

$$V_{j_1}=\frac{l_{t_1}-b}{t_x-t_a} \tag{5}$$

$$V_{j_2}=\frac{l_{t_2}-b}{t_x-t_a} \tag{6}$$

Substitution into equations (3) and (4) gives

$$t_b=\frac{(S_1+S_2)(t_x-t_a)}{2(l_{t_2}-l_{t_1})}+t_a \tag{7}$$

$$l_b=\frac{S_1(l_{t_2}-b)+S_2(l_{t_1}-b)}{2(l_{t_2}-l_{t_1})} \tag{8}$$

If the virtual origin is known, then one can measure the length and position of each micro-segment from a flash radiograph of the broken jet taken at time t_x, and calculate t_b and ℓ_b from equations (7) and (8).

To facilitate comparison of the order of breakup, it is more convenient to write an expression for the relative breakup position of each segment $\bar{\ell}_b$:

$$\bar{l}_b = \frac{l_b - l_m}{l_0 - l_m} = \frac{V_{jb} - V_{jm}}{V_{j0} - V_{jm}} \tag{9}$$

where ℓ_0, ℓ_m, and ℓ_b are respectively the coordinates of the head section, the tail section and the breakup point of a particular micro-segment at the time of breakup t_b; V_{j0}, V_{jm}, V_{jb} are the corresponding velocities of the jet.

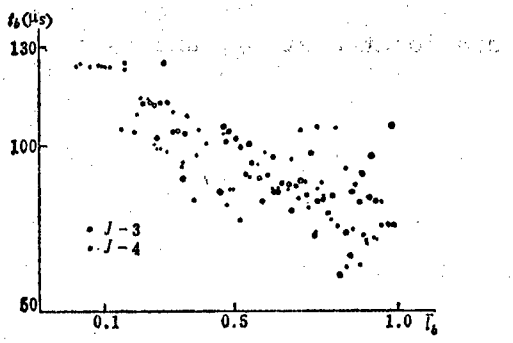

Figure 2. $\bar{\ell}_b$ - t_b Diagram for Single-Cone-Liner Test Charge

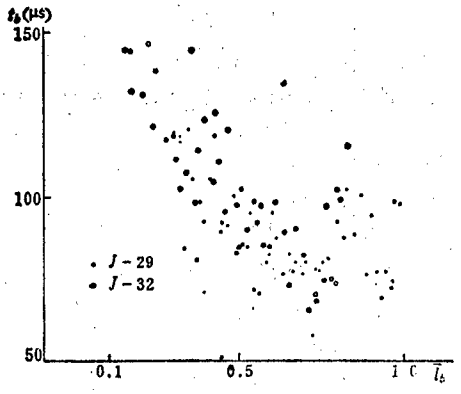

Figure 3. $\bar{\ell}_b$ - t_b Diagram for Double-Cone-Liner Test Charge

The above formula has been used in analyzing flash radiographic data of broken jets for different shaped charge structures. It can be seen from the $\bar{\ell}_b$ - t_b diagram (Figure 2) of single-cone-liner experimental charge that the breakup times corresponding to the micro-segments are widely scattered; the first breakup occurs at 0.85 of $\bar{\ell}_b$, then successive breakups occur in the direction of the tail section. The $\bar{\ell}_b$ - t_b diagram of double-cone-liner experimental charge (Figure 3) shows similar breakup pattern, but the time of breakup beyond the point $\bar{\ell}_b$ = 0.5 occurs much later. Consequently, the jet is more stable and allows deeper penetration than the single-cone-liner jet. This fact has been verified by experiments. Therefore, it is feasible to use the $\bar{\ell}_b$ - t_b diagram for comparing the stability of jets with different shaped charge structures.

Figures 4 and 5 show the combined penetration and breakup curves. In both plots, the breakup points calculated from equations (7) and (8) are indicated, and the trajectories of jet motion are plotted. These trajectories are straight lines whose slopes correspond to the jet velocities at the breakup points. Clearly, the region covered by these straight lines is a region of broken jets, and the region covered by the preceding jet is a region of continuous jets. If the penetration curve (which represents the relationship

between the penetration time and depth of penetration) is also plotted, one can determine whether the penetration process is attributed to a continuous jet or a broken jet; this knowledge is essential for carrying out penetration calculations.

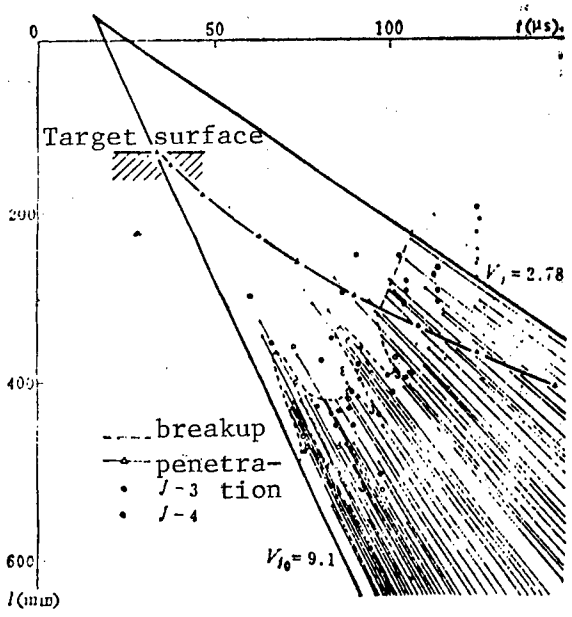

Figure 4. Penetration and Breakup Curves for Single-Cone-Liner Test Charge

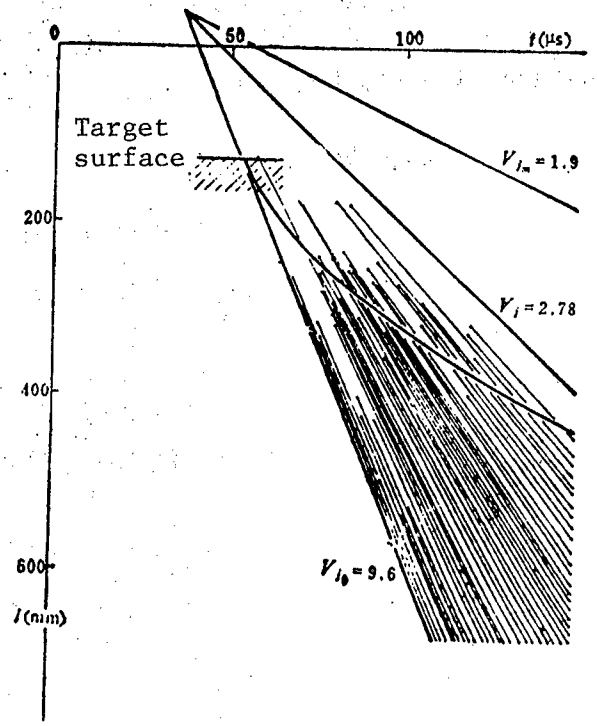

Figure 5. Penetration and Breakup Curves for Double-Cone-Liner Test Charge

II. Derivation of the Penetration Formula of Linear Broken Jets

The above experimental results show that the distribution of jet breakup point is quite irregular; in reality, a continuous jet often breaks up into several segments, then each segment further breaks up into smaller segments. Parallel tests show that the breakup points are random, but for the same charge structure, it is still possible to identify a trend of the breakup points, as shown by the breakup curve in Figure 4. To facilitate calculations without introducing large errors, the curve can be approximated by straight line segments, and the problem is then reduced to one of studying the penetration of linear broken jets.

We shall now derive the penetration formula for a linear broken jet. Consider the jet breakup points (t_{b1}, x_1) and (t_{b2}, x_2) and the corresponding velocities of the micro-segments V_{j1} and V_{j2} (Figure 6); the breakup curve between the two points is assumed to be a straight line. The micro-segment B breaks up at (t,x) and its velocity is V_j; if ϕ is the angle between the breakup line and x-axis, then

$$t = (x_2 - x)\,\mathrm{tg}\,\phi + t_{b_2} \tag{10}$$

Let us examine the micro-segment B at the point (t_{b2}, x_a); its length is dx, and the velocity difference between the two ends is dV_j, thus,

$$x_a = V_j(t_{b_2} - t_a) + b \tag{11}$$

Equation (11) can be differentiated to give:

$$dx_a = dx = -(t_{b_2} - t_a)dV_j \tag{12}$$

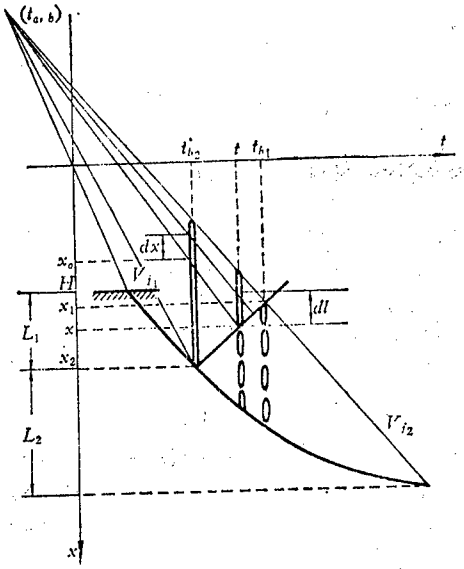

Figure 6. Penetration Calculation of Broken Jet

As the micro-segment B moves forward, its length continues to increase until it reaches the breakup point (t,x) and the length becomes dℓ, after which the length no longer changes. From similar triangles, one obtains

$$dl = \frac{t - t_a}{t_{b_2} - t_a} dx \tag{13}$$

$$= -\frac{(x_2 - b)\operatorname{tg}\phi + t_{b_2} - t_a}{1 + V_j \operatorname{tg}\phi} dV_j$$

If L denotes the depth of penetration, then from quasi-steady penetration theory, one obtains:

$$dL = \frac{U}{V_j - U} dl \tag{14}$$

where U is the penetration velocity. By taking into account the effect of material yield strength based on quasi-steady hydrodynamic theory, the relationship between V_j and U is

$$U=\frac{1}{1-c}\left(V_j-\sqrt{V_j^2c+(1-c)V_{jc}^2}\right)$$

$$c=\frac{\rho_t}{\rho_j} \tag{15}$$

where ρ_t and ρ_j are the densities of the target and the jet respectively, V_{jc} is the critical penetration velocity. Substituting equations (13) and (15) into (14) gives

$$dL=-\left[(x_2-b)\operatorname{tg}\phi+t_{b_2}-t_a\right]\frac{V_j\sqrt{cV_j^2+(1-c)V_{jc}^2}-V_{jc}^2}{(cV_j^2+V_{jc}^2)(1+V_j\operatorname{tg}\phi)}dV_j \tag{16}$$

Equation (16) can be integrated from V_{j1} to V_{j2} to yield:

$$\begin{aligned}
\frac{L}{(x_2-b)s+t_{b_2}-t_a}=&\frac{1}{R}\left[-\sqrt{c}x+\frac{\sqrt{c(1+hs)}}{2s}\ln\frac{\sqrt{1+hs^2}+sx^{1/2}}{\sqrt{1+hs^2}-sx^{1/2}}\right]_{V_{j2}^2+h}^{V_{j1}^2+h}\\
&-\frac{1}{R}\left\{\frac{s\sqrt{c}}{4}(2s^{-2}+h)Y\ln\left|2Y+2x-2s^{-2}-h\right|+0.5\sqrt{c}(s^{-2}+h)\right.\\
&\left.\times\ln\left[\frac{2Y\sqrt{s^{-2}+h}}{xs}+\frac{2(s^{-2}+h)}{xs^2}-2s^{-2}-h\right]\right\}_{s^{-2}-V_{j2}^2}^{s^{-2}-V_{j1}^2}\\
&-\frac{1}{R}\left[\frac{(h-2a^2)s\sqrt{c}}{4}\sqrt{x^2+(h-2a^2)x-ha^2+a^4}\right.\\
&\left.\times\ln\left|2\sqrt{x^2+(h-2a^2)x-ha^2+a^4}+2x+h-2a^2\right|\right.\\
&\left.-\frac{as}{2}\sqrt{c(h-a^2)}\arcsin\frac{(h-2a^2)x-2a^2(h-a^2)}{xh}\right]_{a^2+V_{j2}^2}^{a^2+V_{j1}^2}\\
&+\frac{1}{R}\left(\sqrt{cx}-V_{jc}\sqrt{c}\arctg\frac{\sqrt{x}}{V_{jc}}\right)_{V_{j2}^2+h}^{V_{j1}^2+h}\\
&-\frac{a^2}{a^2s^2+1}\left(s\ln\frac{1+xs}{\sqrt{a^2+x^2}}+\frac{1}{a}\arctg\frac{x}{a}\right)_{V_{j2}}^{V_{j1}}
\end{aligned} \tag{17}$$

where

$$a=\frac{V_{jc}}{\sqrt{c}}$$

$$h=\left(\frac{1}{c}-1\right)V_{jc}^2$$

$$s=\operatorname{tg}\phi$$

$$R=V_{jc}^2s^2+c$$

$$Y=\left[x^2-(2s^{-2}+h)x+s^{-4}+hs^{-2}\right]^{1/2}$$

x is the integration variable, and the upper and lower indices to the right of a parenthesis denote the limits of integration. For example,

$$\left(\sqrt{cx}-V_{j_c}\sqrt{c}\,\text{arc tg}\frac{\sqrt{x}}{V_{j_c}}\right)_{V_{j_2}^2+h}^{V_{j_1}^2+h}=\sqrt{c\,(V_{j_1}^2+h)}-V_{j_c}\sqrt{c}\,\text{arc tg}\frac{\sqrt{V_{j_1}^2+h}}{V_{j_c}}$$
$$-\sqrt{c\,(V_{j_2}^2+h)}+V_{j_c}\sqrt{c}\,\text{arc tg}\frac{\sqrt{V_{j_2}^2+h}}{V_{j_c}}$$

This is the penetration formula for linear broken jets which takes into consideration the effect of material yield strength. Equation (17) can be written as a function of the following parameters:

$$L=L(t_a,\ b,\ x_2,\ t_{b_2},\ \phi,\ c,\ V_{j_c},\ V_{j_1},\ V_{j_2})$$

where x_2, t_{b2} and ϕ reflect the effects of the breakup line and the time of breakup; t_a, b, V_{j1} and V_{j2} reflect the effects of jet velocity distribution and the initial and final velocities of the broken penetration jet; V_{jc} reflects the effect of material strength; and c reflects the effects of the target and jet densities.

In deriving equation (17), the jet at time t_{b2} is divided into micro-segments of equal length dx, but each segment undergoes different degrees of elongation, hence the micro-segments after breakup have unequal lengths. The length and number of micro-segments generally do not agree with those of the actual broken jet. If one neglects the effects of radial scattering and reversal losses of the jet after breakup and the effects of retunneling due to intermittent penetration, then the length and number of the micro-segments do not affect the depth of penetration; in this case, the jet can be divided into infinitesimal segments of length dx. This method of treatment, which was first proposed by F.E. Allison, is feasible when the penetration takes place in the vicinity of the guided[?] explosion altitude, and the flight distance of the broken jet is relatively short. This defines the range of validity of equation (17).

Equation (17) can be simplified when $\left|\frac{(1-c)V_{j_c}^2}{cV_j^2}\right|<1$

Specifically, from equation (16)

$$\sqrt{cV_j^2+(1-c)V_{j_c}^2}=V_j\sqrt{c}\left[1+\frac{(1-c)V_{j_c}^2}{2cV_j^2}+\frac{(1-c)^2V_{j_c}^4}{8c^2V_j^4}+\cdots\right]$$

Under certain conditions, the third and higher order terms in the bracket can be neglected. For example, if c is 0.88 (corresponding to a copper jet penetrating into a steel target), V_{jc} is 1, V_j is 3, then the third term becomes 3.5×10^{-5}, which is much smaller than 1 and therefore negligible. Then, equation (16) can be integrated to yield:

$$\frac{L}{(x_2-b)s+t_{b_2}-t_a}=\frac{1}{s^2V_{j_e}^2+c}\left\{\frac{\sqrt{c}}{s}\left[\frac{1}{2}(sx+1)^2-2(sx+1)+\ln(sx+1)\right]\right.$$

$$+\operatorname{sh}\sqrt{c}\ln(sx+1)-\frac{s\sqrt{c}}{2}x^2-\left(\frac{\operatorname{sh}\sqrt{c}}{2}-sB\sqrt{c}\right)\ln(x^2+B)^{1/2}+x\sqrt{c}$$

$$+\left(\frac{h}{2}-B\right)\sqrt{\frac{c}{B}}\operatorname{arc\,tg}\frac{x}{\sqrt{B}}\Bigg\}_{V_{j2}}^{V_{j1}}-\frac{B}{Bs^2+1}\left[\left|s\ln\frac{1+sV_{j_1}}{\sqrt{B+V_{j_1}^2}}\right.\right.$$

$$\left.\left.+\frac{1}{\sqrt{B}}\operatorname{arc\,tg}\frac{V_{j_1}}{\sqrt{B}}\right|-\left|s\ln\frac{1+sV_{j_2}}{\sqrt{B+V_{j_2}^2}}+\frac{1}{\sqrt{B}}\operatorname{arc\,tg}\frac{V_{j_2}}{\sqrt{B}}\right|\right] \tag{18}$$

where $$B=\frac{V_{j_e}^2}{c}$$

The approximate integral solution (18) is much simpler than equation (17), hence it is more convenient to use whenever conditions permit.

For the case where jet breakup occurs at the same time instant, the angle ϕ becomes zero, and equation (17) is no longer applicable because one of the terms becomes infinite. Therefore, a different formula must be derived. When ϕ is zero, equation (13) becomes:

$$dl=-(t_{b_2}-t_a)dV_j \tag{19}$$

Substitution of equations (15) and (19) into euqation (14) gives:

$$dL=-\frac{V_j-\sqrt{cV_j^2+(1-c)V_{j_e}^2}}{-cV_j+\sqrt{cV_j^2+(1-c)V_{j_e}^2}}(t_{b_2}-t_a)dV_j \tag{20}$$

which can be integrated to yield:

$$L=\frac{t_{b_2}-t_a}{c}\left[\sqrt{cV_{j_1}^2+(1-c)V_{j_e}^2}-\sqrt{cV_{j_2}^2+(1-c)V_{j_e}^2}\right]$$

$$-\frac{V_{j_e}(t_{b_2}-t_a)}{\sqrt{c}}\left\{\operatorname{arc\,tg}\left[\frac{cV_{j_1}^2+(1-c)V_{j_e}^2}{cV_{j_e}^2}\right]^{1/2}-\operatorname{arc\,tg}\left[\frac{cV_{j_2}^2+(1-c)V_{j_e}^2}{cV_{j_e}^2}\right]^{1/2}\right.$$

$$\left.+\operatorname{arc\,tg}\frac{V_{j_1}\sqrt{c}}{V_{j_e}}-\operatorname{arc\,tg}\frac{V_{j_2}\sqrt{c}}{V_{j_e}}\right\} \tag{21}$$

This is the penetration formula for the case of simultaneous jet breakup at time t_{b2}.

When ϕ is equal to 90°, equation (17) must again be modified, as indicated below (see Figure 7).

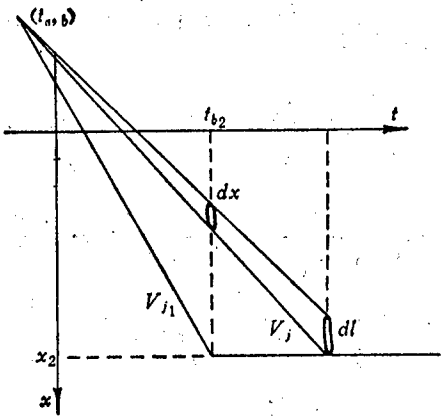

Figure 7. Penetration Calculation of Broken Jet When $\phi = 90°$

$$t = \frac{x_2 - b}{V_j} + t_a$$

$$dx = -(t_{b_2} - t_a) dV_j$$

$$dl = \frac{t - t_a}{t_{b_2} - t_a} dx = -\frac{x_2 - b}{V_j} dV_j$$

$$dL = \frac{U}{V_j - U} dl = -\left[\frac{\sqrt{cV_j^2 + (1-c)V_{jc}^2}}{cV_j^2 + V_{jc}^2} - \frac{V_{jc}^2}{V_j(cV_j^2 + V_{jc}^2)} \right](x_2 - b)\, dV_j \tag{22}$$

Since $V_j > V_{jc}$

Thus, $$\frac{cV_{jc}^2}{cV_j^2 + V_{jc}^2} < 1$$

$$\sqrt{cV_j^2 + (1-c)V_{jc}^2} = (cV_j^2 + V_{jc}^2)^{1/2}\left[1 - \frac{1}{2}\frac{cV_{jc}^2}{cV_j^2 + V_{jc}^2} + \frac{1}{8}\left(\frac{cV_{jc}^2}{cV_j^2 + V_{jc}^2}\right)^2 + \cdots\right]$$

If one chooses c to be 0.88, V_{jc} to be 1.15, V_j to be 3, then the third term inside the bracket of the above formula is 0.002, which is again much smaller than 1 and therefore can be neglected. An approximate integral solution of equation (22) can be obtained as follows:

$$\frac{L}{x_2 - b} = \frac{1}{\sqrt{c}} \ln \frac{V_{j_1}\sqrt{c} + \sqrt{cV_{j_1}^2 + V_{jc}^2}}{V_{j_2}\sqrt{c} + \sqrt{cV_{j_2}^2 + V_{jc}^2}} + \frac{cV_{j_2}}{2\sqrt{cV_{j_2}^2 + V_{jc}^2}} - \frac{cV_{j_1}}{2\sqrt{cV_{j_1}^2 + V_{jc}^2}}$$

$$- \frac{1}{2} \ln \frac{V_{j_1}^2(cV_{j_2}^2 + V_{jc}^2)}{V_{j_2}^2(cV_{j_1}^2 + V_{jc}^2)} \tag{23}$$

This is the penetration formula of broken jet when ϕ is equal to 90°.

The total time of continuous penetration and broken penetration is given by the following formula:

$$t = \frac{1}{V_{j_2}}(H - b + L_1 + L) - t_0 + t_b \tag{24}$$

where V_{j2} is the velocity at time t when it reaches the bottom of the hold, H is the height of explosion, t_0 is the time for the jet to reach the target surface, L_1 is the penetration depth at time t_{b2}, or penetration depth of the continuous jet, and L is the penetration depth of the broken jet.

This completes the derivation of penetration formulas for linear broken jets. Calculations can be carried out by selecting the appropriate formula according to the value of ϕ.

III. Comparison of Test Charge Penetration Calculation With Experimental Results

In the case of test charge penetration with an explosion height of 110 mm, the jet is continuous in the early stages, then changes to broken jet, as manifested by the pear-shaped hole on the target. From Figure 4 one can determine the region of broken jet penetration, and calculate the starting point of broken penetration (with origin at the target surface)

$$L_1 = 200\text{mm}, \quad t = 67\mu\text{s}, \quad \phi = 22^\circ$$

The jet velocity of the test charge is distributed linearly in two sections; i.e., the jet can be visualized as emanating from two virtual points. From the velocity distribution data, one can calculate the jet velocity at the beginning of broken penetration V_{j1} to be 4.389 mm/μs. Since the experiment involves penetration of copper jet against steel target, the approximate form formula (18) can be used. With c = 0.8765, V_{jc} = 1.15 mm/μs, the results of calculation are presented in Table 1. The results of calculation using quasi-steady continuous jet penetration formula including strength consideration (same conditions) are presented in Table 2. P is the total depth of penetration. The calculated results are also plotted in Figure 8, where the solid curve corresponds to the case of continuous jet penetration, and the dashed curve corresponds to the case of broken jet penetration. Figure 8 also shows the experimental P-t values of the test charge. It is seen that in the early stage of penetration, the continuous jet penetration curve is in good agreement with experimental points; during the later stage of penetration, the broken jet penetration curve agrees well with two sets of experimental points with deep penetration, but deviates from the other two sets with shallower penetration. The overall agreement is quite good; the reason that some of the experimental values are too low can be explained by the fact that the theoretical formulae did not consider such factors as radial scattering and reversal losses after the breakup. Therefore, the theoretical results generally agree well with data from a normal jet (deep penetration).

Table 1. Penetration Calculation of Broken Jet

V_j mm/μs	4.389	4	3.5	3	2.5
P mm	200	231.6	273.3	315.8	357.7
t μs	67	83.2	109.7	145.2	194.7

Table 2. Penetration Calculation of Continuous Jet

V_j mm/μs	8.7	6.9	5.75	5.18	4.6	4.14
P mm	16.7	67.4	115.6	146.9	184.9	221.7
t μs	3.55	16.7	32.1	43.7	59.8	77.4
V_j mm/μs	3.8	3.45	3.22	2.99	2.76	2.53
P mm	253.6	290.4	317.6	347.6	380.4	415.8
t μs	94.4	116.5	134.6	156.4	182.8	215.1

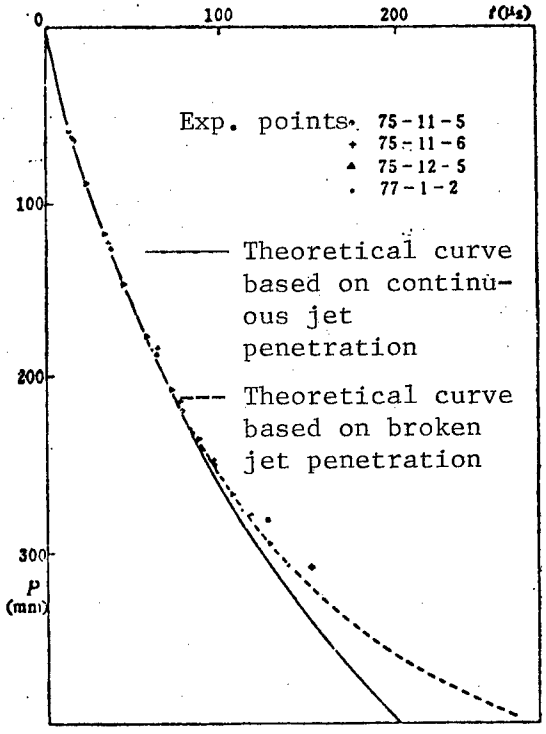

Figure 8. Comparison of Penetration Calculation of Test Charge and Experimental Results

IV. Conclusions

1. Based on Zhou Peiji's method, a formula for calculating the breakup time and breakup position from the flash radiograph of a broken jet is derived. The distribution of breakup points from the radiograph can be used to determine the region of broken penetration to facilitate penetration calculation and to compare the jet stability for different charge structures.

2. By using quasi-steady hydrodynamic theory which takes into consideration the effect of material strength, both analytical and approximate solutions of the problem of penetration of linear broken jets have been obtained, which greatly facilitates the penetration calculation of jets with nonsimultaneous breakup.

3. The broken penetration calculations of a test charge are shown to be in good agreement with experimental data. Good agreement was obtained not only for the total depth of penetration but also for the overall penetration process (expressed in terms of the P-t curve).

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HIGH MAGNETIC FIELD TECHNIQUES, APPLICATIONS IN RESEARCH

Beijing WULI [PHYSICS] in Chinese Vol 13, No 3, Mar 84 pp 162-168

[Article by Gao Bingjun (7559 4426 6874) of the Institute of Plasma Physics, Chinese Academy of Sciences]

[Text] Technically, a high magnetic field generally refers to a magnetic field in excess of 3T ($1T=10^4$ G). The basic technique of generating a high magnetic field is to pass electric current through a multiple-turn coil. The discovery of this technique in the 19th century led to the creation of the modern power industry.

In the late 1930's, F. Bitter of M.I.T. developed the water-cooled magnet design technique[1], which was a major breakthrough in the generation of steady-state high magnetic fields. In the 1950's, large-scale high magnetic field laboratories were established in many countries, and extensive scientific research under high magnetic fields were initiated. Today, the strength of a magnetic field produced by a water-cooled magnet can reach 23.5 T. Furthermore, discovery of the type II superconductor with high critical parameters (H_{c_2}, T_c, J_c) in the early 1960's resulted in the establishment of a large number of superconductor magnet systems whose field strengths were greater than 14T. Today's world record is 17.5T.

By combining the techniques of the water-cooled magnet and the superconductor magnet, it is possible to produce a steady-state field with a maximum strength of 30.1 T[2].

Magnetic fields with higher field strength are produced in the form of pulses. The strength of a pseudo-steady-state (fraction of a second) magnetic field can reach 40 T. The field strength provided by a non-destructive short-pulse (of the order of milliseconds) magnetic field approaches 100 T; field strengths higher than 300 T can also be achieved, but not without damage to the coils and test samples[3].

This article is mainly concerned with steady-state high magnetic field techniques and their applications in scientific research.

I. High Magnetic Field Techniques

1. Water-Cooled Magnets

Table 1 lists the major high-power water-cooled magnets around the world, most of which were built using the Bitter design. This design consists of many hard copper (or copper alloy) discs connected in series and separated by insulating rings; the discs are clamped together by insulated rods to form a rigid thick coil [Fig. 1(a)]. The discs have rows of small holes for axial cooling. The electric current density of the Bitter coil conductor is inversely proportional to the radius. The distribution of axial current density can also be changed by using discs of different thickness. This type of coil has higher efficiency than coils with uniform current density, but it induces large current density at the innermost radial location of the magnet, which causes severe cooling problem and stress problem.

The central magnetic field of a water-cooled magnet is $B_o \propto 1/\sqrt{D_1}$ (D_1 is the effective aperture of the magnet), the required electric power is $W \propto B_o^2$. In order to further increase the central magnetic field or the effective aperture, another type of high magnetic field called the multi-spiral coil [Fig. 1(b)] has been developed over the past decade. It is made of a group of separate thin coils, each of which is a single winding. The individual turns of the coil are held together by epoxide which also serves as an insulator. The cooling water flows through the passageway between two neighboring thin coils; because of the large cooling surface and the efficient heat transfer, high current density can be allowed.

Since the multi-spiral coil is a separate structure, its current density J, the half height of the coil b, and the filling factor λ can be adjusted freely in the radial direction based on optimum design requirements. Consequently, its utilization factor is higher than that of the Bitter coil. The stress of each thin coil can be constrained arbitrarily to comply with the selection requirements of different materials.

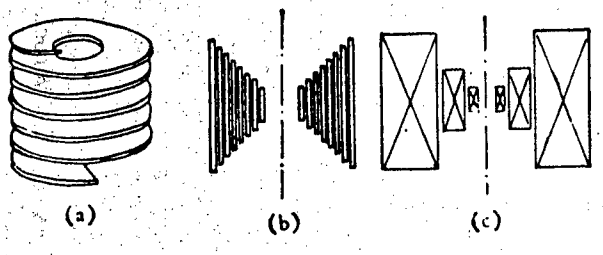

Fig. 1. Water-Cooled Magnet

(a) Bitter coil; (b) Multi-spiral coil;
(c) Multi-stage Bitter coil

Table 1. Major High-Power, Water-Cooled Magnets Around the World

Country	Location	Year Est.	Power (MW)	Type of power supply	field strength (T)	Effective aperture (cm)	Notes
United States	FBNML	1960	10	Generators 4x2.5	8—23.5	25—3.2	
	NRL	1948	8	Rectifiers 6 Generators 2	18	3.2	
	University of Pennsylvania	1968	4		15	2.5	
	University of California	1960	8		12.8	12.2	kerosene-cooled
France	C. E. A. Saclay		4		15	4.2	
	Grenoble (French & German)	1972	10		23.4	5.0	
West Germany	Hochfeld Laboratory	1971	5.5		16	5.0	
Great Britain	Clarendon Laboratory	1945	2		9.5	5.1	
Netherlands	Nijmegen University	1971	6		15	5.3	
Poland	Int. Lab. HMF & L. T., Wroclaw		6.4		20	3.0	
U.S.S.R.	Lebedev Institute		9		18	5.0	
	Kurchatov Institute		6		18	4.0	
Japan	Tohoku University (Sendai)		3.5 8		12	5.0	

At M.I.T., by using conductor discs with radial slots to improve cooling, a multi-stage Bitter coil has been built [Fig. 1(c)].

To build a high-power, water-cooled magnet requires not only a large power source, but also a corresponding pure water cooling system. In addition, in order to withstand the tremendous electromagnetic stress of the high field magnet, high-strength copper alloys (e.g., Cu-Ag, Cu-Al_2O_3), and stainless steel reinforced copper should be considered. However, this will reduce the conductivity of the conductor, and an even larger power source would be required (Fig. 2).

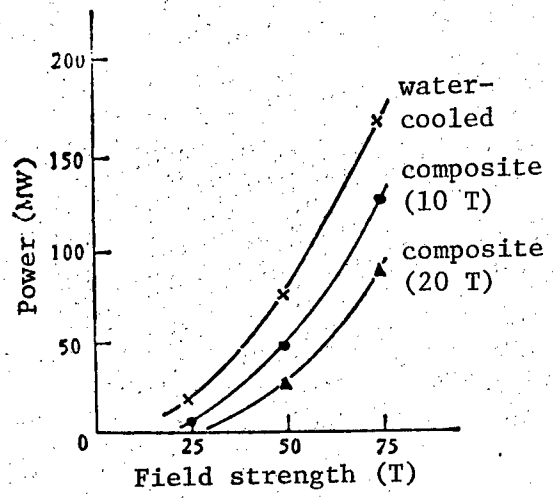

Fig. 2. Power Requirements for a 3-cm Aperture Water-Cooled Magnet and Composite Magnets. The Magnetic Fields of 10 T and 20 T of the Two Composite Magnets Are Provided by the Outer Superconducting Magnets[4]

2. Superconducting Magnets

Multiple fiber Nb-Ti composite line superconducting magnets of various sizes are being widely used today. It is quite routine to achieve field strengths of the order of 8 T; they can reach 10 T if operating at less than 1.8 K. Small magnets which use the Nb_3Sn band to achieve higher field strength are also commercially available, but the use of large magnets with multiple fiber Nb_3Sn lines is only beginning.

In designing superconducting magnets, the critical field strength and critical current density of the superconductor are the key physical parameters. The critical current density of the superconductor J_c decreases with increasing magnetic field within the coil. When the upper critical field is reached, J_c becomes zero; in other words, it is impossible to obtain a magnetic field higher than the upper critical field. For this reason, considerable efforts have been devoted to the development of a superconductor with high critical parameters. In addition, because of the presence of the Lorentz force, stainless steel is often added to the superconducting band to reduce the strain on the brittle A_{15} compound; however, this will result in lower average current density in the winding. Furthermore, since the stored energy in a magnet is proportional to the square of the magnetic field, it can reach a level of megajoules in the case of high magnetic field. When loss of superconductivity occurs, this energy

must be relieved safely using superconducting lines with high copper ratios; this will further reduce the average current density in the winding. Therefore, the dimensions of the magnet and its cost increase rapidly with increasing magnetic field strength (see Fig. 3 and Fig. 4).

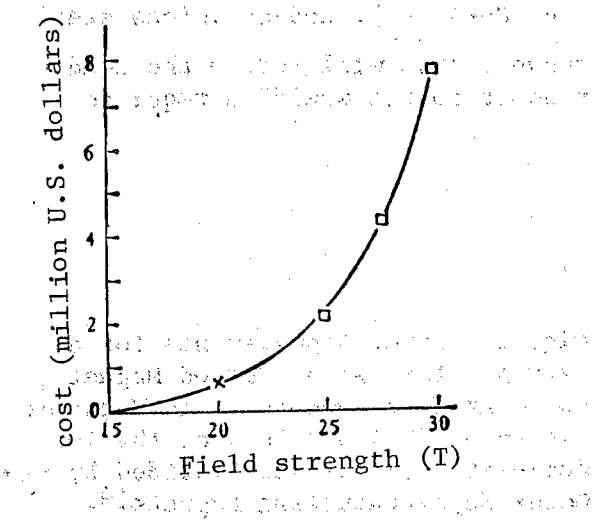

Fig. 3. Cost of a Superconducting Coil With a 5cm Aperture and Field Strength Ranging From 10 T to 17.5 T.[4]

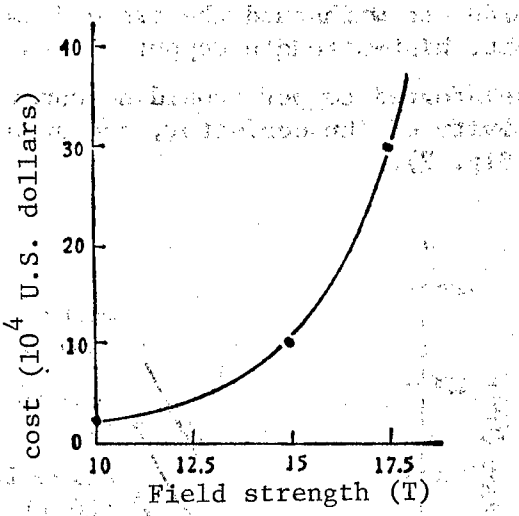

Fig. 4. Estimated Cost of a High Field Superconducting Coil With a 3cm Aperture[4]

3. Composite Magnets

In 1966, Wood of Oxford University and Montgomery of M.I.T. jointly proposed the idea of a composite magnet (which consists of a water-cooled inner magnet and a superconducting outer magnet)[5]. For a water-cooled magnet, most of the power is dissipated on the outer layer of the magnet where the field strength is relatively low. Therefore, by replacing this layer with a superconducting magnet, a higher magnetic field can be obtained with relatively low power (Fig. 2).

Table 2 lists the major composite magnets around the world.

At present, the maximum field strength of a steady-state field with composite magnets is 30.1 T. M.I.T. has plans to reach a field strength of 75 T by 1990. To accomplish this goal requires intensive efforts in developing new high magnetic technology, increasing the output of the power supply, and expanding the scope of superconducting magnets.

Table 2. Major Composite Magnets Around the World

Country	Location	Year estab.	Water-cooled coil		Super-conducting coil (T)	Total field (T)	Aperture (cm)	Present status
			Power (MW)	Field strength (T)				
Great Britain	Oxford University	1975	1.6 2	9.5 13.5	6.5	16 20	5.0 3.0	In operation planned
U.S.	M.I.T.	1977*	9.2	22.1	8	30.1	3.2	Experimental value
Nether-lands	Nijmegen	1978	5.7	17	8	25	3.2	
U.S.S.R.	Kurchatov	1977	5.6	18	6.3	24.3	4.0	
France, Germany	Grenoble		10	20.5	11	31.5	5.0	Under construction
Japan	Tohoku University (Sendai)		3.5 7 7	13 18 18	8 8 12	21 26 30	3.0 3.0 3.0	Under const. planned planned

II. Application of High Magnetic Fields in Scientific Research

In basic scientific research, the exploration and discovery of certain new phenomena and new properties often depend on the presence of extreme conditions such as high pressure, high temperature, low temperature, high-strength field and intense light, etc.

High magnetic fields have a wide range of applications in scientific research and in industrial technology [3,6,7]; numerous international conferences have been devoted to this topic. To limit the scope of this article, our discussion will concentrate on applications in the following basic areas of scientific research.

1. Semiconductor Physics

A high magnetic field often plays an important role in the Landau quantization of carriers in solids. Landau fission causes obvious changes in the density of states which are reflected in many physical phenomena and therefore can be studied experimentally. The experiments can also provide meaningful information about the structure of the electron energy band. For example, it was pointed out that under low temperatures, the application of a high magnetic field causes quantization of the moment of angular momentum, and splitting of the energy band into magnetic subbands. The effective cyclotron mass m_c can be obtained from the energy differences $\hbar\omega_c=\hbar eB/m_c$ between two neighboring magnetic subbands. In order to create Landau fission, it is required that $\hbar\omega_c$ be of the same order as kT, and $\omega_c\tau>1$, which implies that the experiments should be conducted under low temperature and high magnetic field conditions. The properties of semiconductor reverse mold layer, non-crystal silicon, and other types of semiconductors under high magnetic field conditions are today's active research topics [8].

Under the field strength of 30 T that is achievable today, many experiments can be performed. If the field strength is increased to 50-75 T, then one can expect to obtain significant results in the following areas: 1) phase changes in low-dimensional structures; 2) electron structure of magnetic semiconductors; 3) "scanning" of coercion of phonon electron motion; 4) approximate verification of effective mass; 5) study of shallow energy level impurities; and 6) Zeeman fission of deep energy level impurities. In addition, research work can be pursued on topics such as Hall angle saturation of non-compensation materials, condensation of electron-cavity column, cyclotron resonance of heavy mass, true quantum limit of near-degenerate Si and Ge, excimer and excitation effect of two-dimensional magnetic plasma, and negative hydrogen ions of semiconductors in high magnetic field.

2. Metallic Physics

The study of Fermi surfaces of metals can be carried out using such methods as magnetic resistance, measurement based on the de Haas-van Alphen effect, and magnetic penetration. In order to select effective signals, the first two methods require that $\omega_c\tau>1$; the latter method requires $(\Delta E)^2=\mu_B HE_F$.

Therefore, the magnetic field strength must be higher than 15-20 T. In a high magnetic field, these methods will produce some unusual scientific phenomena such as electrically induced phase changes, charge density waves in potassium, strange electron structure of metals, and concentrated dual-element alloys.

The relationship between structural instability and high temperature superconductors is a very important but unresolved problem. In the study of these materials, the measurement of cyclotron resonance and the observation of Fermi surfaces all require a high magnetic field. By using a sufficiently strong magnetic field, one can study the size and shape of the Fermi surfaces of both deformed and undeformed test samples, and directly deduce the relationship among the three parameters: density of states, Fermi surface cluster, and structural stability.

The study of many strange-form low-dimensional solids shows that materials with metallic properties are more common than previously imagined. Examples of these materials include superconducting polymers (e.g., $[SN]_x$) and laminated compounds with only one or two-dimensional conducting structures (e.g., transitional metallic sulfide).

The determination of Fermi surfaces under high magnetic field is very important for understanding their conductive stability; it also provides supporting data for numerous theories that have been proposed to describe the structural phase changes in these systems. In particular, it enables us to determine the effect of electron-electron interaction on phase changes and on variations in conductivity for materials lower than three dimensions.

Another important application of high magnetic field is the study of metallurgical phase change. If there exist differences in the rate or intensity of magnetization between the phases, then an external field can be applied to induce or suppress phase changes. The method of using magnetic field to control phase changes is superior than the temperature induction method in that it can generate the required force for phase change within a much shorter time period; this is very important for the phase changes for non-diffusive martensite. The phenomenon of phase change of martensite has been known for more than 2000 years, but its mechanism is still not well understood. By using a pulsed high magnetic field to induce phase change within the pulse width which will terminate at the end of each pulse, it is possible to freeze the phase change of each stage and observe the intermediate process of phase change. Such an experiment will provide valuable information toward the understanding of the mechanism of crystallization and the process of phase change.

3. Low Temperature Physics

The key to observation of the boson condensation of spin oriented hydrogen is to lower the energy level of the parallel electron spin molecular structure. It is estimated that in a 50 T magnetic field, the boson condensation of spin oriented hydrogen can remain stable for long periods of time to allow observation of the predicted phase changes. The study of the singular properties of such phase changes has significant scientific value.

Among the condensed state materials that have been selected for scientific research, liquid ^3He is one of the system with the most interesting physical properties. Due to the presence of chemical and pairing effects, ferromagnetic moment exists in ^3He-A. But this effect is obscurred by the internal dipole field. By applying a sufficiently high magnetic field, the ferromagnetic moment will become directional and allow direct measurement. In addition, since the effect of dipole field is overcome by the magnetic field, other orientations will take effect, thus making it possible to study this quantum liquid without the influence of dipole field.

4. Superconductivity

To measure the critical parameters (H_{c2}, J_c) of superconducting materials (Nb_3Sn, V_3Ga) and candidate materials (Nb_3Al, Nb_3Ge, $Pb_6Mo_6S_6$) for high fields requires steady-state fields of the order of 20-30 T and 50-60 T respectively.

By varying the field strength, additional information can be gained about the effects of the constituents and defects (disorder, vacancy, dislocation) of materials on the critical parameters (T_c, H_c, J_c). The interaction between crystal lattice defects and magnetic flux lattice is the foundation of magnetic flux blocking [?]. It is of particular importance to study the empirical formula for practical superconductor under high magnetic field $J_c x B$ = constant, in order to search for a new method of magnetic flux (blocking) which will remove the severe limitation of this formula. This is clearly important for the design of high field magnets.

Under a magnetic field of almost 100 T, it is necessary to modify the magnetic phase line as the field energy approaches the condensation energy in order to study the existence of electron 3-body pairing. By studying the variation of H_{c2} with temperature, one can test the different theories concerning paramagnetic limits, spin orbit coupling effect, and other basic properties of high field superconductors.

5. Magnetism

Up to now, the origin of ferromagnetism is still a mystery. Since a 1 T magnetic field can produce an equivalent 1.4 K Zeeman fission (relative to g=2 spin), a 75 T magnetic field will produce Zeeman energy of the order of 100 K. Such a field contains many exchange fields between ferromagnetic and antiferromagnetic materials, and therefore will produce various types of phase changes induced by the magnetic field. Experimental results of applying a 20-35 T field to Pd and YCo_2 show that while Pd is the most important exchange enhancement element in the Periodic Table, its long-range polarization makes it a basic ingredient of the 3d elements (e.g., Fe,Co). But no evidence of induced ferromagnetism has been observed in Pd, only in YCo_2. Since the exchange enhancement part of the magnetic moment is expected to vary with D^3H^3 (D is exchange enhancement), a 50-75 T field can increase the resolution by two orders of magnitude. To study the coupling between magnetic impurities in the basic ingredients of enhancement is of significant value because the

range of coupling between impurities increases with increasing rate of magnetization; hence, a magnetic field can be used to modulate this coupling. This is very important for understanding diluted alloys, spin class, and non-diluted systems.

The multiple critical points of magnetically ordered systems make it possible to verify modern theories on phase change and calibration laws. During the past few years significant progress has been made; it is now possible to explain the phenomenon of magnetic to non-magnetic phase change in matter. The most interesting phenomenon is the dual critical point of anti-ferromagnets, where the phase boundaries of spin deflection, anti-ferromagnet and paramagnet intersect. To study this region requires a magnetic field which is several times greater than the critical field $H_c=(2H_EH_A)^{\frac{1}{2}}$ (where H_E and H_A are respectively the exchange field and the anisotropic field), or approximately 15-30 T. Another important application of this critical phenomenon is that the Ising ground state model in a lateral magnetic field can be represented by a two-dimensional Ising model without magnetic field at arbitrary temperature levels.

6. Atomic and Molecular Spectroscopy

The main topics in the field include the study of (Gao-li-de-bo) state, the study of moving Stark lines and reverse intersections, and the problem of collision dynamics.

A high magnetic field can change the collision cross section by inducing precession of the moment of momentum of the atomic or molecular ground state and excited states. For example, in a Na-Na* resonant collision, due to the fixed transport of Zeeman energy level, the contribution of long-range dipole-dipole interaction to excited transport is almost eliminated. In principle, this allows investigation of the individual higher order, non-resonant terms of the interaction potential, which were concealed by the resonant dipole terms in zero field. Under high magnetic field, the study of collision dynamics is directly correlated with collision time, and may lead to a new concept about the collision potential. The higher the magnetic field, the shorter is the collision time; as a consequence, the collision dynamics will be changed drastically.

Under ordinary magnetic field, the study of (Gao-li-de-bo) state where comparison can be made between the Zeeman energy and Coulomb energy requires that the electrons have very high quantum number n. Raising the magnetic field strength will increase the number of systems to be studied.

The study of high magnetic field spectroscopy is also closely connected with research in astronomy. The experimental simulation of astronomical spectrum in a laboratory with 100-1000 T magnetic field will be a valuable tool for studying a White Dwarf and other objects.

7. Chemistry

The use of high magnetic field can help answer three of the unresolved questions in chemistry: (1) understand the complex effect in the condensation phase; (2) understand the key factors that control atomic dynamics in molecules and during the formation of molecules; (3) understand the electron structure of highly excited state.

By using magnetic research methods, we can improve our understanding about chemical activity; with this method, we study the reaction mechanism by observing variations in the relative reaction speed in the complex system. In particular, we can study new chemical properties induced by changes of the molecular wave function in a magnetic field, and the magnetically induced anisotropic effect in an isotropic chemical reaction system; we can also study light induced chemical reaction methods, including magnetically sensitive single-line state and triple-line state of molecules in a high magnetic field. For a free electron, a 1 T magnetic field can produce fission energy of the order of 1.4 K; a high magnetic field can produce Zeeman fission of the order of several hundred K; thus, a realistic correction can be applied to the chemical activation process.

The chemical reaction dynamics of the gaseous and condensation phase and on the surface clearly will be affected by a magnetic field of the order of kT. A sufficiently high magnetic field can effectively change the potential energy surface which controls the proximity and interaction between atoms and molecules. Furthermore, due to the action of anti-magnetism, the molecules will become partially directional, thus providing a new method for studying the steric hindrance effect of chemical reactions.

The mass resolution of ion cyclotron resonance varies with B^2. Based on current standard, the limit is 1000 mass units at 7.5 T; if the magnetic field is increased to 100 T, then the mass limit will reach 200,000. This makes it possible to study biological systems, multinuclei complexes, and organic metals with large molecular weight. Ion cyclotron resonance of the order of 100 T can also be used to study materials weighing less than 1μg, thus providing a useful way for exploring a variety of biological systems and for isotope separation.

8. Biology

In a magnetic field, the synchronized precession of dipoles of identical atoms constitutes the macroscopic effect of magnetic resonance. Oscilloscopes constructed on the basis of the magnetic resonance phenomenon are used extensively in the study of molecular structures of biological systems such as proteins, nucleic acid, lipid, and carbohydrates. In order to further improve resolution and sensitivity, efforts are being made to increase the magnetic field strength. For example, in studying the structure of transfer RNA solution, one cannot resolve the low-field displacement NHN resonance under a currently achievable magnetic field (approximately 14 T); the measurement of its resonance number is quite controversial. But if the field strength is increased to 20-30 T, sufficiently high resolution can be achieved to allow such investigations as the folding and non-folding of heat energy and the measurement

of structural energy. If the field strength is increased to 75 T, then it would be possible to investigate the interaction between antibodies and antigens, the structure and function of hemoglobin, and to measure and graph the complex of lipoprotein-reaction composite enzyme and the bound locations of acceptors. If the three-dimensional NMR imaging technique is used to study the internal structure of a single cell, it may be possible to gain a better understanding of the chemical process and the mass transport mechanism within the cell.

9. Plasma Physics

Magnetic confinement is an important technique for studying plasmas. By applying magnetic field to a laser illuminated region, laser-induced damages to the surfaces of solids will be greatly diminished. Studies of the effect of high magnetic field on the reverse scattering of laser radiation of a plasma show that the field component perpendicular to the direction of laser propagation reduces the intensity of the reverse scattering of plasma acoustic waves. The effect of magnetic field is much more pronounced on light-weight hydrogen ions than on heavy helium ions. In a laser heated plasma, these magnetic effects play an important role in studying laser fusion.

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TRITIUM IN WATER SAMPLES MEASURED BY CYCLOTRON

Shanghai HE JISHU [NUCLEAR TECHNIQUES] in Chinese No 5, Oct 84 pp 30-32

[Article by Zhou Shanzhu [0719 0810 6999], Pan Haochang [3382 3185 2490], Lin Junying [2651 0193 5391], Wu Jiezheng [0702 0094 1767], Yao Chongjue [1902 1504 6030], Gu Genxiang [7357 2704 4382], and Li Honggui [2621 7703 6311]: "Measurement of ^{3}H Content in Water Sample With a Cyclotron"]

[Text] Abstract

The ^{3}H content of water samples collected at Yuquan Shan outside Beijing was measured with an ultrasensitive mass spectrometer. After electrolytic enrichment, the water samples were electrolytically converted into gases and introduced into the ion source of a cyclotron. The ^{3}H ions were accelerated to high energy (10 MeV) and detected by a silicon detector telescope. Measurements were made by comparing with a sample containing a known concentration of ^{3}H. The measured result of 50 ^{3}H units is consistent with the results obtained by a β decay method.

I. Introduction

The technique of using accelerator as an ultrasensitive mass spectrometer is a new area of nuclear technology developed in the last few years. Some have referred to this method as the nuclear accelerator spectroscopy.[1] In 1977, R. A. Muller of the University of California, D. E. Nelson, et al., of the Simon Fraser University, and McMaster University in Canada, and a joint effort by C. L. Bennett, et al. of the Rochester University, General Ion Company in the United States and University of Toronto in Canada, have independently reported their ^{3}H and ^{14}C measurements using existing cyclotrons and ^{14}C measurements using tandem Van de Graaf accelerators. These efforts have received wide attention. Today many countries including the United States, Canada, Great Britain and France are developing research and applications in this area and some laboratories are building special accelerators for this purpose.

In this new technique, the isotope to be measured is first introduced into the accelerator ion source, then ionized and accelerated to a high energy and the atoms are then detected and counted. In contrast to the decay method

where only a small fraction of the atoms are detected during the counting period, the new method detects most of the atoms of the nuclear spices of interest. Therefore, the sensitivity is several orders of magnitude higher. Moreover, when the technique is used for dating, it requires much less sample and can determine much older ages.

In order to explore the feasibility of developing the new nuclear spectroscopy using the cyclotron at the Shanghai Institute of Nuclear Research, we determined the ^3H content of the Yuquan Shan Water in Beijing and compared the results with the decay method.

II. Principles and Method

1. Principles

The minute amount of ^3H in water comes from the atmosphere via rainfall. Tritium in the atmosphere is in turn produced in the spallation reaction of the (n_1t) in the cosmic ray and oxygen and nitrogen in the atmosphere. Since the cosmic ray intensity is considered to be a constant, the ^3H content in surface water is also constant. (Actually, since the lifetime of ^3H is not long enough and the mixture on the earth surface is not uniform, the ^3H content in water varies from location to location.) Once the water is separated from the atmosphere, the tritium in the water can only decay and cannot be replenished. Consequently, a measure of the ^3H content in water determines the age of the water. This has important applications not only in cosmic ray physics, but also in hydrology, meterology and oceanography.

We originally planned to determine the age of the underground water at Yuquan Shan by comparing it with contemporary water of a known ^3H content because this method does not require changing the frequency of the accelerator and the same detection system may be used. However, because the tritium content in the atmosphere has been disrupted by the hydrogen bomb explosions in the atmosphere has been disrupted by the hydrogen bomb explosions in the atmosphere since the 1950's, dating by the conventional decay method can no longer work. Therefore, we determined the ^3H content of the Yuquan Shan water by comparison with a standard sample of known ^3H content.

In order to date a sample, Muller[2] selected a 24-year-old water sample collected before the explosion of the hydrogen bomb and used the T/D ratio method. The advantage of this method is that no sample change is necessary. However, because D and T cannot be accelerated simultaneously (they have different charge-to-mass ratios) and cannot be detected by the same counter (the D current is too strong and must be collected with a Farady cylinder), some errors were introduced and the measured age was 33 years.

2. Identification and detection of Tritium

Measurements were performed in the 1.2 meter cyclotron at the Shanghai Institute of Nuclear Research. Figure 1 shows the schematic diagram of the experimental arrangement.

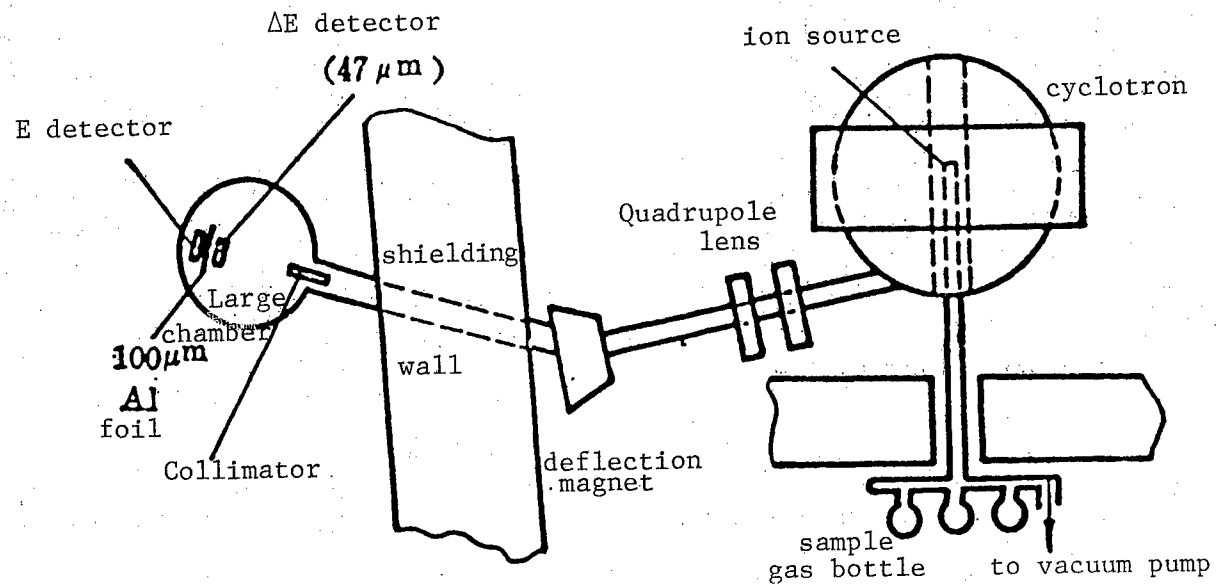

Figure 1. Experimental Set-up

To find the optimum condition of accelerating and detecting ^3H, we used a telescope system containing a gold-silicon surface barrier type detector with ΔE = 47 μm and E = 500 μm. In the actual data taking, since the ^3H count was very low, we did not use the product spectrum; instead, we inserted a 100 μm aluminum foil between the ΔE detector and the E detector and measured the E spectrum directly. Figure 2 is a block diagram of the circuit.

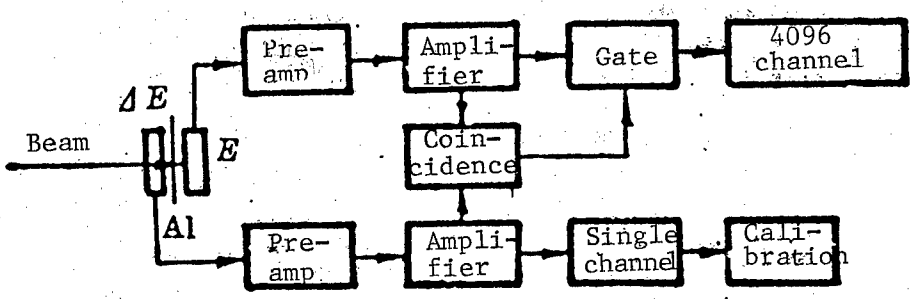

Figure 2. Measurement Circuit

With the inserted aluminum foil, the 10 MeV ^3He is totally blocked and any DH or H_3 molecules are also broken up and stopped, thus, a single ^3H peak appears in the energy spectrum. After calibration, the energy is found to be 6.4 MeV, in agreement with the residual energy of the 10 MeV ^3H passing through 47 μm silicon and 100 μm aluminum.

Figure 3 shows a typical energy spectrum. The small peak to the left is ^3H and the large peak to the right is He. The ^3He peak comes from the air

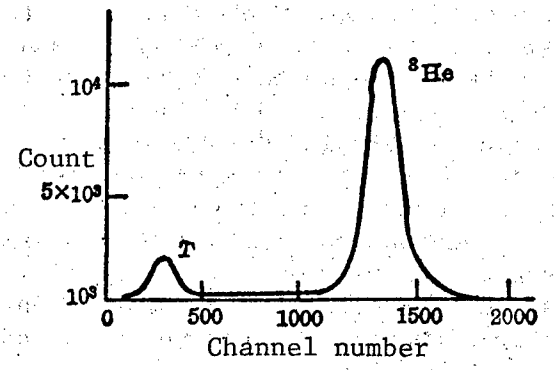

Figure 3. ΔE Detector Energy Spectrum

intentionally mixed into the tritium gas for beam monitoring purposes. We use the ^{3}He count in the ΔE detector to calibrate the ^{3}H count and eliminate the effects of instabilities in the cyclotron operation and input gas current.

3. Sample preparation

The enriched water sample is electrolytically dissociated into gas and then introduced into the cyclotron ion source. Since the dissociation rates in the electrolysis process are different for heavy and light isotopes, the electrolysis and the gas delivery cannot be done simultaneously. The gas collected from the electrolysis is first homogenized and then delivered to the ion source. Specifically, we take 5 ml each of the enriched sample water, the standard sample water, and the unenriched deionized deep well water (as a background), electrolytically dissociate them under the same conditions and control the residual solution at 1 ml. (Theoretical calculation shows that 4.01 ml of solution is needed to produce 5 liters of gas.) The hydrogen, deuterium and tritium mixture obtained from the electrolysis is collected into a 5 liter glass bulb using an oil free method and each bulb contains the gas from one sample.

The anode of the electrolysis bath is a 1.2 cm diameter platinum tube and the cathode is a spiral-shaped platinum wire. During the electrolysis, 2 grams of GR grade P_2O_3 is added to the solution, the current density is 100 mA/cm^2. The current should not be too large, otherwise the electrolysis proceeds too fast and the solution heats up and results in a loss of tritium. The volume of the solution before electrolytic dissociation is calibrated with a semi-micro analytic balance and the error is less than 1 percent.

4. Gas system

In the course of the experiment, the gas samples from the three different waters (the standard water, the Yuquan Shan spring water and the background water with a very low tritium content) are measured alternatively. To improve the sensitivity, the first two bottles of water are electrolytically enriched at the Beijing Institute of Nuclear Energy. The standard water is

the tap water at the Beijing Institute and the tritium content is determined by the decay method to be 100 units (one unit of tritium corresponds to one tritium atom in 10^{18} hydrogen atoms). The standard water is enriched 409 times, the Yuquan Shan water is enriched 140 times and the third bottle, groundwater taken 150 m below the earth's surface at the Shanghai Institute, contains almost no tritium and it is only ion-exchanged and not enriched. Each water sample is electrolytically dissociated into gas and the gas fills up a 5 liter glass bulb. It takes only a few seconds to change sample. In order to eliminate the residual gas from the previous sample, the system is pumped for a few tens of seconds after the previous sample gas is shut off and before the next sample gas is turned on, the initial counts of the new sample are also discarded. The alternative measurements have good reproducibility. During the sample change, all the operating parameters of the cyclotron remain unchanged.

III. Results and Discussion

The measurement results are listed in the table below. The relatively high background may be due to the small amount of tritium water used in the tuning of the cyclotron and the detection system. Based on the ^3H content of the standard water (100 units), we computed the ^3H content of the Yuquan Shan water to be 50 units. Using a β-decay method, the Beijing Institute of Nuclear Energy measured a result of 52 units.

Measurement Data

Sample	Enrichment	^3H count	Monitor count	^3H count / Monitor count	Time (min)
Standard water	409	79,343	44,139	1.80 ± 0.01	104
Yuquan Shan water	140	5,268	10,881	0.484 ± 0.008	35
Background water	1	18,600	88,959	0.209 ± 0.002	58

The errors quoted in the table above are only the statistical errors, the main source of error is the monitoring of the beam. We originally planned to add an equal amount of ^3He gas to each gas sample to normalize the tritium count because the mass difference between ^3He and T is very small (6.6×10^{-6}). Under favorable operating conditions, the count ratio of ^3He and T is quite stable. We have performed a test in which 6 data points were taken within 15 minutes, each counting lasted 100 seconds. Even though the absolute value of the counts varied greatly, the ratio remained constant within 2.6 percent. As it turned out the ^3He gas we planned to use contained about 1 percent tritium and it was therefore not used in the actual measurements. Instead, we mixed an equal amount of air into each sample bottle and used the ^3He in the air to monitor the beam. Since the amount is extremely minute, the tritium contained in the air may be totally neglected.

In cooperation with the operating team of the cyclotron, we have successfully accelerated tritium and ^3He ion for the first time. In order to lower the tritium background, a new ion source was put in before the official data taking began.

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9698
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ZERO POWER REACTOR CALIBRATED

Shanghai HE JISHU [NUCLEAR TECHNIQUES] in Chinese No 5, Oct 84 pp 64-65

[Article by Hou Hailin [0186 3189 2651], Du Kangsen [2629 1660 2773], Zhang Yingji [1728 2503 4614], Feng Jinzhang [7458 6930 4545], Liang Jianzong [2733 1696 1350] and Chen Cheng [7115 4453] of the Shanghai Institute of Nuclear Research: "Power Calibration of Zero-Power Reactor of Uranium Water Lattice"]

[Text] In the measurement of the reactor power, thermodynamic methods are often used at high reactor power and various reactor physics methods, such as the neutron source method, the neutron statistics method[1] and the total fission rate of the whole sector, are used at low reactor power.

The neutron source method has relatively large uncertainty and the neutron statistics method requires the detector efficiency in the reactor and the β_{eff} of the reactor, both difficult to obtain. The total fission rate method finds the reactor power from the measured total fission rate of the reactor and circumvents the shortcomings of the first two methods but still relies on the measurement of the relative distribution of the fission rate.

Methods for measuring the total fission rate include the gold foil activation method,[2,3] the solid trace method,[4] and the radiochemistry method.[5] The total fission rate depends on the thermal neutron flux and the fuel cadmium ratio. It can also be obtained by measuring the absolute fission number of one gram of ^{235}U. In this work, we used the usual gold foil activation method and took into account the necessary corrections.

I. Experimental Principle

In a ^{235}U reactor, the reactor power P and the total fission rate F are related in the following manner:

$$P = F/K \qquad K = 3.14 \times 10^{10} \text{ fission/W.s} \tag{1}$$

The total fission rate can be obtained as follows: Place the activated gold foil in a certain location in the reactor core and measure the absolute thermal neutron flux ϕ_{th}^{Au} at that point. The absolute fission rate at this point can then be obtained and the total fission rate of the reactor can be computed from the relative distribution of the fission rate. Specifically,

$$F = N_5 \cdot \sigma_f \cdot \phi_{th}^{Au} \cdot CRf/(CRf-1) \cdot \bar{f}/f_{Au} \qquad (2)$$

where N_5 is total number of ^{235}U nuclei in the reactor, σ_f is the fission cross-section of ^{235}U, CRf is the cadmium ratio of the fuel at the location of the gold foil, f_{Au} is the relative fission rate at that point and $\bar{f}$ is the average relative fission rate of the whole reactor.

ϕ_{th}^{Au} may be found from the following equation:

$$\phi_{th}^{Au} = \frac{A\lambda F_{th}}{N_{Au}\sigma_a \frac{CR_{Au}}{CR_{Au}-1}(1-e^{-\lambda t})(e^{-\lambda t_1}-e^{-\lambda t_2})G_{th}} \qquad (3)$$

where A is absolute decay activity of ^{198}Au measured from time t_1 to t_2, λ is the decay constant of ^{198}Au, N_{Au} is the number of gold nuclei in the foil, σ_a is the absorption cross section of gold, CR_{Au} is the cadmium ratio of gold at the measurement point, t is the irradiation time, t_1 is the time from the end of the irradiation to the beginning of the measurement and t_2 is the time from the end of the irradiation to the end of the measurement, F_{th} is the falling factor of the thermal flux and G_{th} is the thermal self-shielding factor.

Since neither gold nor ^{235}U are 1/V absorbers, the reactor neutrons are not monoenergetic. Therefore, σ_f and σ_a in the equation above are both average cross-sections corresponding to the neutron energy spectrum for the particular experimental conditions.

If the location of the gold foil is taken to be the normalization point of the relative measurements, then

$$\bar{f}/f_{Au} = \bar{f}_z \cdot \bar{f}_r \qquad (4)$$

where $\bar{f}_z$ and $\bar{f}_r$ are respectively the normalized axial and radial average relative fission rates.

II. Experimental Measurement

The measurements were made in a low concentration uranium, boron water moderator zero power reactor. The grid distance of the core was 10.4 mm and the 3506 fuel rods were formed into an approximately cylindrical configuration. The reactor core loading height was 702 mm and the fuel elements had a diameter of 6.55 mm.

1) Measurement of the absolute activation of the gold foil

The gold foil had a thickness of 27 μm and a diameter of 6.5 mm. It was placed at the half height of a fuel rod at the center of the reactor. After irradiation, the activity of the ^{198}Au was measured with a right cylindrical coaxial single-ended Ge(Li) detector. The spectrometer was earlier calibrated for relative and absolute efficiency.[6] The absolute activity of the gold foil

was then obtained from the area under the 412 keV γray of ^{198}Au and corrected for the detector efficiency and γray branching ratio.

2) Measurement of $\bar{f}_z$ and $\bar{f}_r$

The relative distribution of the fission rate was obtained from the γactivity of the fission fragments. The simple method not only directly reflects the fission in the fuel but also avoids the operation of disassembling the fuel element and placing or retrieving the activated foil. From the relative distribution of the fission rate, $\bar{f}_z$ was found to be 0.816, $\bar{f}_r$ was 0.585 and $\bar{f}/f_{Au}$ was 0.477.

3) Measurement of CR_f and CR_{Au}

The gold foil used in the CR_{Au} measurement was the same as that for the absolute activity measurement. The uranium foil used in the CR_f measurement was made by electroplating an aluminum foil with the uranium fuel from the same reactor. The diameter of the foil was 6.5 mm and the surface density of uranium was 0.9 mg/cm^2. In the cadmium measurement the cadmium plate was 0.5 mm thick and the measured results are CR_f = 6.39, and CR_{Au} = 1.62.

III. Correction Terms

1) Fast neutron fission correction

The experimental principles only considered the thermal fission of ^{235}U, but the ^{238}U, contained in the fuel also contribute to the power via the fast fission. The experimentally obtained total fission rate must therefore be multiplied by the neutron fission coefficient ε. Theoretical calculations show that ε = 1.038 in our experiment.

2) Cross-section correction

Based on the theoretical neutron energy spectrum from 0-10 MeV for the reactor used, we computed an average fission cross section of 420.3 b for ^{235}U and an average capture cross-section of 75.9 b for ^{197}Au.

3) Fall-off correction for the gold foil thermal shielding and thermal flux

Calculations yielded a self-shielding factor G_{th} of 0.967 for the gold foil and the correction factor for the flux fall-off caused by the disturbance of the neutron field by the gold foil was F_{th} = 1.002.

4) Cadmium ratio correction

Since the cadmium still absorbed some superheated neutrons, the measured cadmium ratio tended to be too large and should be divided by the computed correction factors F_{Cd}^{Au} = 1.01 and Ft_{Cd} = 1.00.

5) Irradiation time correction

Since the gold foil was irradiated not only during the steady reactor power but also during the period when the power was increased. The latter should be included in the irradiation time.

IV. Experimental Results

The table below shows the thermal neutron flux at the center of the reactor at the half height of the fuel element, the total fission rate of the whole reactor, the experimental results and errors of the reactor power and the reactor control panel reading, all for a boron concentration of 939 ± 4 ppm in the boron water moderator.

ϕAu^{th} $(n/cm^2 \cdot s) \times 10^6$	4.82 ± 0.24
F (fission/s) $\times 10^{10}$	6.78 ± 0.35
P(W)	2.05 ± 0.13
Control panel reading	
Power meter (1)	1.46×10^{-8}A
Power meter (2)	1.52×10^{-8}A
γ dosimeter	64μR/s

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9698
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ISOTOPE SEPARATION IN PLASMAS BY RESONANCE METHODS

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[Article by Wang Long [3769 7893] of the Institute of Physics, Chinese Academy of Sciences]

[Text] The methods commonly used today in industry for isotope (primarily Uranium) separation are the gaseous diffusion method and the centrifugal method. Both methods are based on the minute mass differences between the isotopes; hence the efficiency of each stage of separation is rather poor. For example, in the gaseous diffusion method, the UF_6 gas is passed through a porous wall; for different isotopes, the diffusion speeds are inversely proportional to the square roots of their masses. By using this method to separate ^{235}U and ^{238}U, the concentration of ^{235}U through each stage can only be raised by a factor of 1.004. Therefore, to raise the natural concentration of ^{235}U from 0.7 percent to 3 percent (as required by light water reactor) requires a total of 1250 separation elements. For this reason, the equipment cost and operating cost of this type of facility are very high. In the centrifugal method, two different isotopes are separated by centrifugal force under high-speed rotation; this method consumes less energy, but it requires even more elements.

New separation methods under investigation include the laser method and the plasma method. The laser method, which is the more mature of the two, uses lasers to stimulate the atoms or molecules of a certain isotope to its highest energy state, thus increasing its chemical activity; it then uses other techniques to separate it from other isotopes. The advantage of this method is that it requires relatively few separation elements; the equipment cost and operating cost are only a fraction of those of the existing methods.

The plasma method can be subdivided into the rotation method and the resonance method. The rotation method is based on the same principle as the gas centrifugal method described above, but since it uses a magnetic field to propel the charged particles, higher rotational speeds can be achieved because the system is not limited by the material strength of the container. However, the higher rotational speed causes the temperature to rise, which adversely affects the separation process and utlimately limits its efficiency.

The resonance method uses the interaction between wave and particle in the vicinity of the ion cyclotron frequency to separate the isotopes. It is based on the fact that charged particles under the influence of a magnetic field are in gydroscopic motion in the direction perpendicular to the magnetic field. The cyclotron frequency is $\omega = qB/cm$, where B is the magnetic field strength, q is the electric charge of the particle, m is the particle mass, and c is the speed of light. If the frequency of an externally applied alternating magnetic field is equal to or approaches the cyclotron frequency of a particular isotope, then resonance with this type of ion will occur.

The first such method proposed that successfully separated isotopes in the laboratory was the ion cyclotron resonsance method [1]. In this method, a wave whose frequency is equal to the cyclotron resonance frequency of the isotope ions to be separated is applied to a plasma in a uniform magnetic field; this will cause the selected isotope ions to accelerate in the direction perpendicular to the magnetic field, and be collected by a cold tungsten belt with a bias voltage.

To accomplish the separation requires that the following two conditions be met. First, there must be sufficient time to accelerate the ions, i.e.,

$$\omega\tau\ (\Delta M/M) > 1, \tag{1}$$

where $\tau = L/v_{11}$, L is the length of the test apparatus, v_{11} is the average particle velocity in the direction parallel to the magnetic field; ω is the circular frequency of the alternating field; M is the mass of the isotope; and ΔM is the mass difference between the isotopes.

Second, the number of collisions must be sufficiently small, because collisions will cause the resonant particles to change their direction of motion from that which is perpendicular to the magnetic field to a parallel direction, or to transfer their kinetic energy to the non-resonant particles. This requires

$$(\upsilon/\omega) < (\Delta M/M), \tag{2}$$

where υ is the mean collision frequency of the high-energy ions.

Two apparatuses are used in the experiment described in Ref. [1]. One is a static plasma generator (the Q machine), whose main parameters are as follows: plasma diameter 5.7 cm, length 1 m; maximum static magnetic field 4kG; spatial uniformity of the magnetic field $\Delta B/B$ less than 0.3 percent; typical plasma parameters are $n = 10^{10}$-10^{11} cm^{-3}, $T_e \simeq T_i \simeq 0.2$eV. A long solenoid is used to generate an 80-100 kHz high frequency field. With 300 W of pumping power, the induced electric field strength in the angular direction is E=0.06r, where r is the radial coordinate in cm, and the field strength is in V/cm.

Another apparatus is a d.c. discharge unit. The maximum magnetic field produced by the superconductor magnet is 20 kG, with spatial uniformity $\Delta B/B$ less than 0.7 percent. It uses two electrodes located at one end of the apparatus to generate a high-frequency field by direct excitation. This method of excitation only requires 3 W of power. The results obtained from both apparatuses are consistent.

The high-energy ions are collected by a radial energy analyzer with a positive bias voltage. Figure 1 presents the experimental results of a potassium plasma (containing two isotopes ^{39}K and ^{41}K). The plot (a) shows the variation of collector current with respect to the static magnetic field for a fixed frequency (88.6 kHz) and for different values of bias voltages. This current is proportional to the number of high-energy ions which exceed the corresponding energy level. It can be seen that the accelerations of different isotope ions ^{39}K and ^{41}K take place at different resonant frequencies. The plot (b) shows the variation of collector current with respoect to the analyzer bias voltage for the following cases: high frequency wave is absent; and high frequency wave resonates with either the ^{39}K ions or the ^{41}K ions. It is seen that the ions can be accelerated to 50eV under resonant conditions. The fact that these two curves are almost straight lines illustrates that the velocities perpendicular to the magnetic field approach the Maxwellian distribution.

A cold tungsten belt (-5°C) with a 4V bias voltage is used to collect high-energy ions; after 30 minutes of operation, the tungsten belt and the collected macroscopic samples are sent to a 4-electrode mass filtering device to be analyzed. It is found that during ^{41}K resonant excitation, the ratio of isotopes ^{39}K and ^{41}K in the sample has increased from the natural concentration of 0.07 to 4.

This method has been used to create resonant conditions for more than 30 different types of atoms and molecules. It can also be used in conjunction with other physical or chemical methods to improve separation efficiency.

In order to mitigate the conflicting requirements between the separation conditions (1) and (2) (increasing the temperature is favorable in satisfying the 2nd condition but unfavorable for the 1st condition), one can use the harmonics of the ion cyclotron resonant frequency. In the experiment described in Ref.[2], isotope resonances up to the 13th harmonic have been observed.

The second plasma resonance method is called the mass dynamic potential method in the vicinity of the ion cyclotron frequency [3]. The so-called mass dynamic force refers to a non-linear force acting on the charged particles due to electric oscillations of the electro-magnetic wave or the plasma. It can be represented by a potential function φ_j:

$$F_j = -\nabla\varphi_j \tag{3}$$

In the vicinity of the cyclotron resonance frequency, this mass dynamic potential can be expressed as

$$\varphi_j = q_j^2 E_o^2/2m_j(\omega-\Omega_j)\omega, \tag{4}$$

where q_j is the electric charge of this particle; E_o is the electric field amplitude of the left circularly polarized plane electromagnetic wave; m_j is the particle mass; and Ω_j is the cyclotron frequency of this particle.

If the masses of two isotopes are very close to each other, one can select the frequency of the alternating field to be in between the cyclotron resonant frequencies of the two types of ions, i.e., $\Omega_1<\omega\Omega_2$. In this case, the mass dynamic potentials of the two types of ions will be of opposite sign; in other words, the gradient of the high-frequency field will push the different ions toward opposite directions, thus achieving direct spatial separation of the isotopes.

The dispersion relation of an ion cyclotron wave in a cold plasma is

$$\frac{k^2c^2}{\omega 2} = 1 - \sum_j \frac{\omega^2_{pj}}{\Omega j(\omega-\Omega j)} \tag{5}$$

where k is the wave vector; $\omega_{pj}=q_j\sqrt{n_j/m_j}$ is the plasma frequency of the jth type particle; Ω_j, q_j, n_j, m_j are respectively the cyclotron frequency, electric charge, density, and mass of this type of particles. If $m_1 \gtrless m_2$, $\Omega_2 \gtrless \Omega_1$, and $n_1>>n_2$, then in the case of ^{235}U and ^{238}U, one can let

$$\omega = (\Omega_1+\Omega_2)/2. \tag{6}$$

The dispersion relation (5) can be approximated by

$$k^2c^2 = -\omega^2_{p1}/\alpha \tag{7}$$

where α is a very small number.

$$0 < \alpha = [(\Omega_2 - \Omega_1)/2\Omega_1] \ll 1. \tag{8}$$

From equation (7), the fact that k is an imaginary number implies wave attenuation and the possibility of forming a field gradient to produce mass dynamic forces for separating the isotope ions.

If $n_1<<n_2$, then in the case of ^{39}K and ^{41}K, one can again use equation (6) to arrive at an approximation for equation (5)

$$k^2c^2 = \omega^2_{p2}/\alpha. \tag{9}$$

Here k is a real number, which implies no wave attenuation, and a standing wave is required to form the field gradient.

Let us again consider the first situation. When the condition of thermodynamic equilibrium is reached, the two types of particles have the following distribution:

$$n_1 = n_{10}\exp(-m_1E_0^2/2\alpha T B_0^2), \tag{10}$$

$$n_2 = \text{const}\, n_1 \exp(m_1 E_0^2/\alpha T_i B_0^2), \tag{11}$$

where $T = T_e + T_i$, T_e, T_i are respectively the electron temperature and ion temperature. By substituting the density formula of the first type of ions (10) into the dispersion relation (7), a non-linear wave equation for the electric field distribution is obtained:

$$\frac{d^2E_0}{dz^2} - \frac{1}{\alpha}\,\omega_{p10}^2 \exp\left(-\frac{m_1 E_0^2}{2\alpha T B_0^2}\right) E_0 = 0. \tag{12}$$

If wave excitation occurs at z=0, then the solution of equation (12) is as shown in Figure 2. The characteristic length of the separation region is

$$L = \sqrt{\alpha}/\omega_{p10} = (\alpha m_1/q_1^2 n_{10})^{1/2}. \tag{13}$$

The enrichment efficiency can be defined by the following formula:

$$\varepsilon = (n_2/n_1)_{max}/(n_2/n_1)_{min}. \tag{14}$$

From equations (10), (11), one obtains

$$\varepsilon = \exp(m_1 E_0^2/\alpha T_i B_0^2). \tag{15}$$

In the same reference, a set of design parameters were also suggested for the separation of ^{235}U and ^{238}U:

B_o=25 kG; $n_1=10^{11}\text{cm}^{-3}$; T_i=2eV, T_e=4eV; E_{omax}=30 V/m; L=8.89 m.

With this type of apparatus, the enrichment efficiency of uranium whose two isotopes exist in natural ratios can be as high as e=32.

The above calculation is based on the expression of mass dynamic potential in the vicinity of the cyclotron resonant frequency (4). According to this formula, a singular point exists when $\omega \to \Omega_j$, $\varphi_j \to \infty$. This is a result of using the adiabatic approximation in deriving equation (4), where it is assumed that variation in electric field is very small within a region of one cyclotron radius. Therefore, the range of validity of equation (4) is $\ell \gg v/(\omega-\Omega_j)$, where ℓ is the scalar length of the electric field gradient, v is the particle velocity. When the frequency approaches that of the cyclotron frequency, this condition is no longer true, hence one must consider the non-adiabatic effects on the mass dynamic potential in the vicinity of the cyclotron frequency.

In Ref. [4], an experimental setup as shown in Figure 3 is used for this purpose. This setup is 137 cm long and has a radius of 7.3 cm; a 1.8 kG uniform magnetic field is generated in the axial direction, and a pair of semi-circular antennas are used to generate a high-frequency electric field. The characteristic length ℓ of the high-frequency field gradient can be varied by varying the antenna length. At one end of the apparatus, a control grid is

used to allow a beam of fixed-energy ions to pass through the apparatus for a sustained period of 20 microseconds; they are collected by a collector electrode located at the other end of the apparatus. If the mass dynamic potential exceeds the particle kinetic energy, then the ion beam will not be able to reach the collector electrode.

The results are shown in Figure 4, where experimentally obtained points of mass dynamic potential are plotted as a function of the frequency for different values of the parameters ℓ, $\nu/\ell\Omega$. The solid curves represent the theoretically calculated results for different values of $\nu/\ell\Omega$. This figure shows good agreement between experimental and theoretical results and also confirms that the mass dynamic potential is a function of frequency and $\nu/\ell\Omega$. When $\nu/\ell\Omega=0$, it is given by the adiabatic approximation (4); when $\nu/\ell\Omega>0$, its peak value does not occur at $\omega=\Omega$, but rather at $\omega\,\Omega+1.7\nu/\ell$. The corresponding mass dynamic potential is approximately 0.75 times that of the adiabatic value at the same frequency.

Since the non-adiabatic effect tends to lower the mass dynamic potential, it is desirable in an isotope separation apparatus to have the mass dynamic potential at the applied frequency as close to the adiabatic value as possible. This requires that

$$\omega > (\Omega + 2\nu/\ell) \tag{16}$$

Equation (6) indicates that $\omega - \Omega$ is fixed, hence the particle thermal velocity has a maximum value given by

$$\beta = [8\pi n_1 T_{11}/B_o^2] < [(\Delta M/M)^3/32] \tag{17}$$

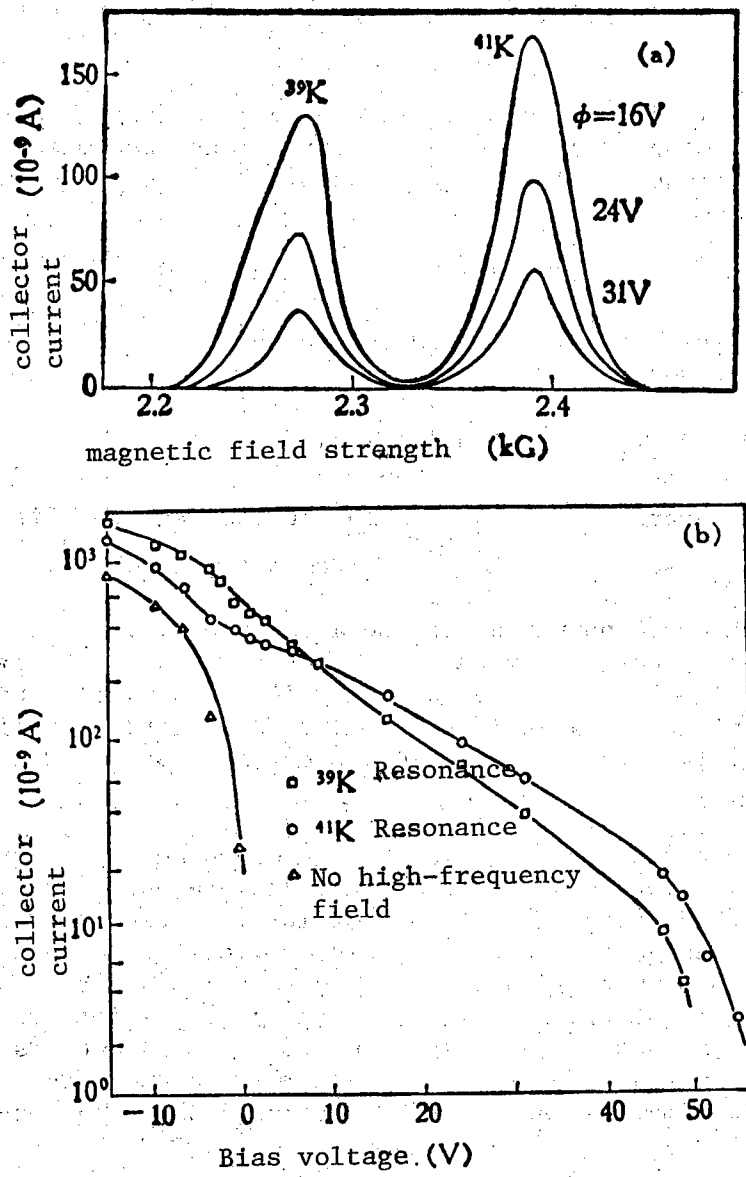
where T_{11} is the temperature of ions parallel to the magnetic field. For the separation of uranium isotopes, it is required that $\beta<1.3\times10^{-7}$.

The method of mass dynamic potential can be used to achieve direct spatial isotope separation, but due to limitation on the value of β, the density must be kept fairly low, thus limiting the operating efficiency. In addition, the range of variation of the characteristic length for a given isotope is very small; consequently, it is difficult to perform this type of experiment using a small apparatus.

In view of the demands for isotopes and the deficiencies of existing isotope separation methods, various new separation methods are being considered. The plasma resonance methods described in this article, particularly the 2nd method, were introduced quite recently; it is difficult to predict at this time whether they can compete with other methods in industrial production. It should be pointed out that the main advantage of these methods is that one can separate different isotopes by simply changing the parameters of the test apparatus. In other words, compared with the laser methods, this method can be easily applied to simulate the separation of uranium using non-radioactive isotopes.

This research work is also closely connected with some of the important problems in plasma physics such as the excitation, propagation and modal transfer of waves in plasma, the non-linear interaction between waves and plasma, as well as some of the important applications of the fusion phenomenon such as cyclotron resonant heating of ions, high-frequency plugs for open-ended apparatus, and the removal of impurities. All these problems can be investigated by further development of this field of research.

Fig. 1. (a) ion current measured by a radial energy analyzer; variations in the static magnetic field correspond to resonances of ^{39}K and ^{41}K, ϕ is the bias voltage applied to the analyzer; (b) relationship between the ion current and analyzer bias voltage for the cases of no high frequency field, ^{39}K resonance, and ^{41}K resonance.



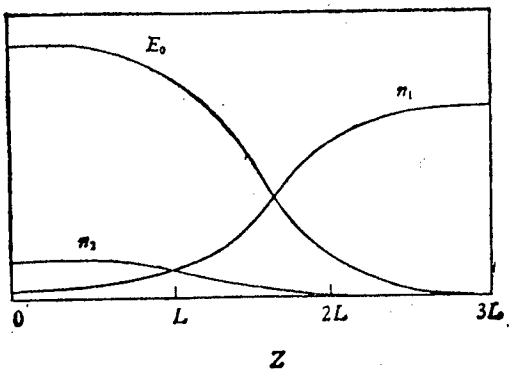
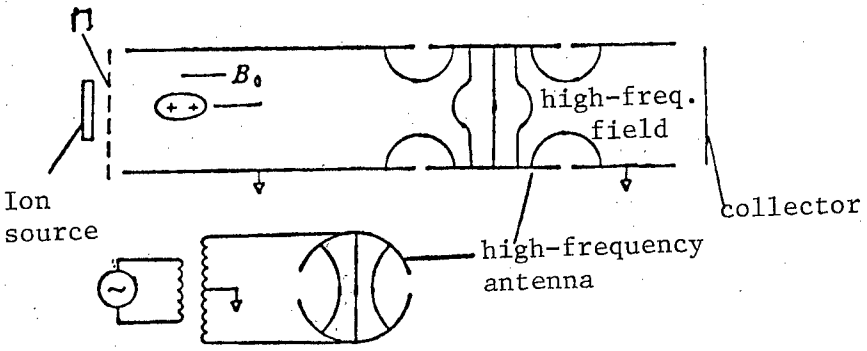


Fig. 2. Axial Distribution of the Electric Field Amplitude E_o and the Densities of Two Isotopes n_1, n_2.

Fig. 3. Apparatus for Measuring the Mass Dynamic Potential in the Vicinity of Cyclotron Resonant Frequency



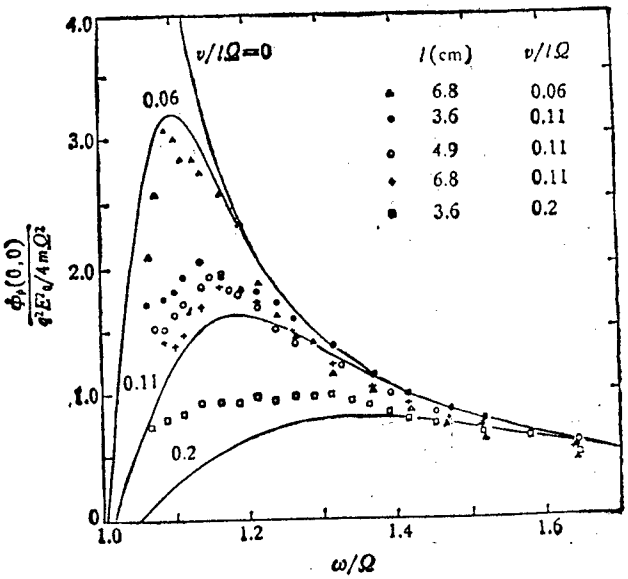


Fig. 4. Experimental and Theoretical Results of the Relationship Between Mass Dynamic Potential and Frequency for Different Values of the Parameters ℓ and $v/\ell\Omega$.

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3012
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ROBOT MANUFACTURING TECHNOLOGY TO BE FURTHER DEVELOPED

OW270000 Beijing XINHUA Domestic Service in Chinese 0011 GMT 25 Dec 84

[Article by Correspondent Ye Lu]

[Text] Beijing, 25 Dec (XINHUA)--It is reported that China has decided to further develop robot-manufacturing technology.

For this purpose, the Commission for National Defense Science, Technology, and Industry recently held a forum in Beijing on developing robots. Speaking at the forum, Qian Xuesen, the renowned scientist, who is vice chairman of the commission, said: The robot is an automatic machine with specially designed functions. It is an important part of high technology and the new technological revolution of the 1980's, which combines a machine with electric power and operates with human intelligence. With the research facilities and technology for developing and manufacturing robots, departments under the commission, as well as relevant scientific research institutes, are duty-bound to take up this important task.

Experts and professors attending the forum offered many good opinions and suggestions for further developing China's robot manufacturing technology. They held: It is necessary to make full use, as quickly as possible, of the robots already installed at all units. At the same time, it is necessary to conduct the research and manufacture of robots for work in hazardous environments, such as high temperatures, poisonous gas, strong vibration, dusty air, loud noise, and strong radiation. The experts urged departments concerned to organize China's robot research and manufacturing forces, unify their planning, and coordinate their efforts, in order to quickly raise the level of our country's robot research work.

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BRIEFS

NEW METEOROLOGICAL SATELLITE--Changchun, 25 Dec (XINHUA)--China is building a data processing center for a meteorological satellite it is going to launch. The center will be completed next year, according to participants at a conference of provincial meteorological directors ending here today. The data for the launching is still not known, but the satellite will be named "Fengyun No. 1." Ways of improving meteorological services were discussed at the 10-day conference. A satellite data processing system imported from the United States is already in trial use. It was acquired with U.N. aid. [Beijing XINHUA in English 1608 GMT 25 Dec 84 OW]

SATELLITE ATLAS COMPILED--Beijing, 24 Dec (XINHUA)--An earth science atlas of China has been compiled from satellite images by the Chinese Academy of Sciences' Institute of Applied Remote-sensing and the National Remote-sensing Center. The first comprehensive, multidisciplinary atlas of China, it shows land cover and utilization, hydrological dynamics, regional morphology, and tectonics. It is the work of 90 scientists from universities, institutes, and industrial departments. [Text] [Beijing XINHUA in English 0241 GMT 24 Dec 84 OW]

FIRST SOLAR ENERGY CAR--Beijing, 23 Dec (XINHUA)--Chinese technicians have developed an automobile powered by solar energy, GUANGMING RIBAO reported today. The first of its kind in China, the car is made of glass fiber, aluminum, and other light materials, with a solar energy collector composed of 2,808 monocrystal silicon chips. Weighing 159 kilograms, the three-wheeled car can travel at a speed of 20 kilometers per hour. Its two storage batteries can keep it going for more than 100 kilometers in overcast weather conditions and at night. The vehicle was made by six middle-aged and young technicians at the "sun-day" new technology development company of the Hubei Provincial Metals Society. [Text] [Beijing XINHUA in English 0718 GMT 23 Dec 84 OW]

AVALANCHE DETECTOR DEVELOPED--Chengdu, 9 Dec (XINHUA)--The Xinan [Southwest] Technology and Physics Research Institute has, for the first time, succeeded in developing a low-voltage silicon photoelectric detector for avalanches and its modules. Both these two achievements have passed technical inspection. These two inventions have further advanced China's laser information technology, and can be widely applied to civil communications, geological prospecting, and weather forecasting. [Summary] [Beijing XINHUA Domestic Service in Chinese 0148 GMT 9 Dec 84 OW]

EARLY TREATMENT OF WARTIME WOUNDED DISCUSSED

Beijing JIEFANGJUN YIXUE ZAZHI [MEDICAL JOURNAL OF THE CHINESE PEOPLE'S LIBERATION ARMY] in Chinese No 3, June 1984 pp 226-228

[Article by Lu Xichang [7120 3556 2512] and Shen Yugan [3088 0060 1631], of the Institute of Field Surgery, Third Army Medical University: "Early Treatment of Wounded Personnel in Wartime"]

[Text] In order to ensure the treatment of wounded personnel in wartime, it is imperative to put into practice the principle of treatment classification that is, immediate first aid and evacuation from the front, definitive treatment and specialized treatment. Even so, there will still be deaths among the wounded. The post-injury death rate hinges upon whether evacuation and treatment are speedy and appropriate. During World War II, the Allied casualty rate was 4.5 percent. The American troops, because they used airlift evacuation, lowered the casualty rate to 2.4 during advances and to 2 percent after advances. On the battlefield the proportion of dead to wounded is generally 1 3/4. The deadliness of weaponry is rising, but the battle casualty rate is falling steadily. The reason lies in advances in surgical skills and related research. The key to improved treatment quality is in technological level, organization and equipment. This article gives a brief account of treatment and related question.

I. The Principle of Projectile-Induced Injury

The initial-velocity capabilities of modern small arms are all comparatively high, generally more than 760 m/s. The initial velocity of shrapnel from artillery shell and grenade explosions can also reach 1,200 to 1,800 m/s. Owing to the irregular shapes of shell fragments, their velocity drops quickly and they frequently result in serious tissue lacerations. Bullets are streamlined, and they also spin in flight, easily piercing the tissues and often leaving an exit wound that is larger than the entrance wound.

High velocity is the major factor in projectile-induced injury. When a flying projectile enters a person's body, its entire energy is transmitted to the location of impact and surrounding tissues. The immediate destructive effect of the bullet's forward momentus is easy to understand. What we need to stress recognition of is the bullet's lateral impulsive force. This causes every tissue cell and water particle surrounding the bullet

also to become a lateral projectile, producing an implosive effect. Beneath the effect of the lateral impulsive force, the tissues form a temporary empty cavity, and the cavity walls undergo several expansions and contractions. The resulting scale of tissue damage extends far beyond the actual bullet trajectory. Even those blood vessels, nerves and bones not directly hit also may suffer injury. If a bone is hit and broken, bone fragments then become dispersed like secondary bullet fragments, transmitting energy in different directions and causing further injury. Consequently, during debridement one must consider not only the wound trajectory, but also the surrounding tissues. These tissues are devitalized after sustaining an injury, and, moreover, they are ischemic. As a result, we can summarize the effects of induced injury as follows: (1) fatal injury, in which tissue destruction occurs near major organs; (2) ordinary organ and tissue injuries and defects, such as open pheumothorax and ruptures and punctures of the body cavity and viscera; (3) blood loss and shock; (4) wound contamination and infection.

In wartime, more than 90 percent of all injuries are caused by firearms, as related above. However, non-projectile injuries, such as burns, punctures, frostbite and injuries caused by collapsing construction materials and automobile accidents, also commonly occur. As for injury from nuclear weaponry, chemical preparations and biological warfare, they require another seminar.

II. Wound Contamination and Infection

Bacterial contamination of open wounds in wartime is inevitable. Disregarding, for the moment, a consideration of whether the bullet carries bacteria in flight, it nevertheless can carry or draw bacteria from surrounding skin, clothing or body environments into the wound. Also, at the time of wounding, soil or dirt particles, perspiration and post-explosion sediment particles all may contaminate the wound. The existence of a large quantity of devitalized or necrotic tissue in the wound provides the conditions for large-scale bacterial reproduction. This is not in the least similar to the case for non-projectile injuries. Consequently, under most conditions, suturing is not initially practice on gunshot and explosion wounds, and delayed suturing is practiced instead. In wartime there are explicit, strict stipulations regarding this. Physicians, whether they are from the armed forces or from the locality, all must strictly observe this practice.

The degree of bacterial contamination is partly determined by whether there is timely use of dressings to cover the wound. Bacteria are evident, reproducing and invading the wound, within 4 to 12 hours after injury. Within 24 to 36 hours, symptoms of inflammation appear. The ideal is to conduct debridement within 6 hours of the injury. The earliest reasonable use of antibiotics may delay the bacterial invasion.

III. Stages and Treatments

With respect to the stages of wound treatment, some specialists feel that "early" refers to within three days of injury, and "late" refers to 3 months

after injury. However, the experiences of emergency surgery in peacetime indicate to us that the 1st hour after injury is the "golden hour" for rescue, by and large having already determined whether the gravely wounded can survive or not. This is also true during wartime. The keys to early treatment are in "volume resuscitation" and emergency lifesaving techniques. It is essential, as soon as possible, to carry out definitive treatment, drainage, and closure of the thoracic cavity, exploratory laparotomy, plaster setting of fractures and prudent use of anti-infection agents. Satisfactory accomplishment of these early treatments not only can reduce mortality, but also prepares the way for specialists and follow-up treatments. From the perspective of military medicine, early treatment is precisely what is practiced under extraordinary battlefield and war-zone conditions, and is largely a feature of field surgery.

IV. First Aid

Hemostasis, wound binding, fixation and transport are the four major first aid techniques at the front, and prevention and elimination of respiratory tract obstructions, as well as first aid for asphyxia, should also be included. Wound binding is not only for the purpose of reducing wound contamination; a more important function is hemostasis. The emphasis below is on a discussion of hemostasis problems on the battlefield.

The major cause of battlefield death from injury to the extermities is due to hemorrhaging. Proficiency in the application of pressure bindings and other hemostatic techniques can thus effectively reduce mortality. First of all, we should make clear that first aid at the front cannot rely upon tourniquets for hemostasis. Evidence of past suitable usage of tourniquets by the Soviet Army on the battlefield is quite extensive, but strict stipulations in rescue units must be reexamined and corrected. Other than for tears of the femoral artery, we should as far as possible reduce the use of tourniquets, because effective pressure binding is generally adequate to stanch hemorrhaging. Western nations stress the use of compresses for hemostasis, and they do not use tourniquets unless all other methods have failed. Consequently, they no longer provide tourniquets to non-medical personnel. We believe that a simple denial of the place of tourniquets in first aid is not sufficiently convincing. Although there are several drawbacks to tourniquets, nevertheless they are still one effective method in the practice of first aid at the front. Consequently, we also need improvement to enable the many first-stage medical personnel to attend to and handle the series of problems with hemostatic effects. Only when a tourniquet approaches a pressure that is much higher than the systolic pressure is it able to cut off the entire flow of blood in the limb, thereby stanching hemorrhaging from the wound or broken blood vessels. Recent research proves that the narrower the tourniquet, such as a rubber tube or a length of cord, the higher the necessary hemostatic pressure. A pressure 9 or 10 times greater than original systolic pressure will be necessary before hemorrhaging will be blocked. That is to say, within a certain range, the degree of narrowness of the tourniquet has an exponential relationship to the hemostatic pressure. This is vastly different from the hemostatic principle of direct pressure binding, which applies local and

surrounding pressure on the wound. Under direct pressure conditions, factors are immediately produced that are favorable to hemostasis or to slowing the loss of blood. For example, owing to external, static pressure, blood vessel ruptures shrink, the difference between internal and external pressure in the blood vessels is reduced and where long, not narrow, sections of blood vessels receive pressure, the caliber of the blood vessel shrinks. In this fashion, the actual necessary hemostatic pressure need not exceed the patient's current systolic pressure to be effective, and the flow of blood into the extremities can be basically maintained. According to practice and to the theory of fluid mechanics, herein also lies the basic principle that enables pressure binding to effectively stanch active hemorrhaging. The pressure of suitably narrow tourniquets is close to, but must be higher than systolic pressure. Furthermore, the influence of limb circumference and lining thickness is also reduced, and this is beneficial in preventing local contusions and nerve paralysis. A tourniquet should be twined on the proximal side of the wound, but no precise position is stressed. Attention should be paid to using an appropriate degree of tightness, and the tourniquet generally should not be used for longer than two hours. As early as possible, pressure binding and forcep clamps should be carefully used to substitute for the tourniquet in order to shorten as far as possible the length of time that blood flow to the extremities is blocked.

V. Follow-Up Treatment

When wounded personnel reach their battalion or regiment medical aid stations, those who have had their wounds properly dressed should not have the wounds reopened for purposes of inspection or "changing the dressing," but only for resuscitation or implementation of emergency lifesaving techniques. Open thoracic wounds can lead to fatal paradoxical respiration, and dressings with an external rubberized plaster cast or several pins on the opening should be used to ensure against this. Prior to evacuation, wounded personnel with bone fractures should have them appropriately set. During the evacuation it should be ensured that the respiratory tracts of those with facila, jaw or craniocerebral injuries and those with shock are unobstructed.

A. Resuscitation of Shock Victims

The majority of cases of wartime shock are due to loss of blood. Treatment should start with assurance that the respiratory tract is unobstructed, discovery and control of large-scale hemorrhaging and also restoration of blood volume. Venous transfusion is the most important key. Supplementation of fluid volume should exceed blood and fluid loss by 2 to 3 times. Because the total volume of blood needed during shock is in excess of normal blood volume, functional extracellular fluid during shock is also very low and must be supplemented. Crystalline fluids, colloidal fluids or blood all may be used. A rapid infusion of 2,000-3,000 ml of balanced saline solution can quickly reverse or temporarily alleviate shock, but a balanced saline solution cannot completely replace blood transfusion. Excessive transfusions may lead to pulmonary edema and induce crises of acute respiratory distress syndrome and cardiac failure.

Division medical aid stations and front line hospitals should become surgical centers, implementing definitive treatment and becoming known for excellent surgical aid. In division medical aid stations we must further categorize wounded personnel and arrange priorities in surgical procedures and a sequential order of treatments. We cannot base these upon the order of arrival; rather we should base them upon the types of wounds and the existing evacuation conditions, as well as upon the effectiveness of the surgical procedure. The sequence of emergency surgery should be as follows: first priority should be placed on saving wounded personnel with open thoracic wounds, obstructions of the resp ratory tract, major hemorrhaging and shock, pericardial tamponing, visceral protrusion and serious fractures; second priority should be on splanchnic perforation, blood vessel injury and craniocerebral trauma with non-serious cerebral lesions; third priority should be on soft-tissue injury, injury to jaw, face, eye or spinal column, and most fractures.

VI. Debridement and Delayed Suturing

If there is a large quantity of devitalized tissue surrounding the bullet trajectory, it becomes, along with clots and foreign bodies, a potential source of infection. The purpose of debridement is precisely for excision of devitalized tissue, elimination of clots and foreign bodies, drainage and assurance that blood circulation can reach the surface of the wound. In wartime debridement, even if it is done very carefully, it is difficult to ensure excision of all necrotic and devitalized tissue. If the wound is immediately sutured, it is possible that infection will set in, and, if it is not drained, the infection may spread. Consequently, suturing cannot be done soon after debridement. Wounded personnel who are not sutured after debridement are safer during evacuation, and we should adhere to this principle.

A. Wounds That Require Initial Suturing

This refers to face, scalp and abdominal wounds. The muscles of the thoracic wall can be sutured and ragged skin left open. Nerves and muscle tendons in wounds to the hand are best covered with soft tissue. In the limbs, blood vessels and sutured parts of nerves and muscle tendons should also be covered, but the skin should not be sutured. The synovial membranes of joints and the capsula articularis must be sutured and the skin left open.

Those who do not need to have tissue excised are those with mostly small, superficial surface wounds of the jaw, face or scalp, or with penetrating wounds that are apparently neither contaminated nor necrotic. The surgical essentials are to shave the hair, wash the area with soap and clean water, remove only a modicum of the jagged skin edge, vertically incise the skin and the fascia profunda, expose all dead space, eliminate clots and foreign bodies and excise devitalized tissues. All muscle that is malacic, darkened in color and does not contract when pricked or bleed when cut must be excised. Bone fragments, except for tiny chips, should all be retained. Those that are heavily contaminated can be removed, cleaned and replaced again, because bone defects are much more difficult to treat than is

osteomyelitis. Nerves and muscle tendons can be repaired later. Antibiotic powders can be used locally, but wounds that are dressed and recovered should not be tamponaded

B. Delayed Suturing

The majority of wounds to the extremities require debridement and delayed suturing. Treatment of these wounds is divided into two steps: first debridement, and secondly delayed suturing within 3 to 6 days. External cleanliness of the wound is the indicator for suturing. If the wound is still not clean, or if it is infected, then antibiotic treatment should be continued for 10 to 14 days. Wait until after there is granulation overjet of the wound to do the second-stage suturing, or, after 3 weeks, graft the wound closed.

C. Surgery on Infected Wounds

Owing to the combat environment, the transport difficulties and the disadvantageous topographic or climatic factors, time may be lost in sending wounded personnel to a unit where surgery can be performed. When infection has already set in on the wound, the surgical procedure can only be to incise the skin and the fascia profunda in order to help in complete decompression and drainage.

VI. Treatment of Wounds at Various Loci

A. Cephalic Wounds

In wounds that penetrate the skull, survival and evacuation are possible only if hemorrhaging is not severe and if resulting blood can be drained off. It must be borne in mind that comatose wounded personnel may suffer respiratory tract obstruction at any time. Operational procedure is to eliminate foreign bodies, clots and tiny free bone fragments. However, to avoid uncontrolled hemorrhaging, bone fragments that are near sagittal and occipital sinuses should not be moved. If the dura mater is lacerated, then isotomic saline should be used to wash out broken tissues. If the dura mater cannot be sutured, it can be left open, antibiotic powder can be sprinkled into the wound and the scalp can be sutured.

B. Thoracic Wounds

Those with grave chest wounds frequently die at the front, yet the state of purely pulmonary injury may not be too serious. When the bullet hits a lung, its cavity-forming effect is not serious. The blood vessels in the injured part close quickly, the circulatory blood pressure is low and, owing to the release of prothrombin, the flow of blood can be quickly stopped. Vibrations of the hemothorax caused by the action of respiration and heart palpitations maintain the fluid, and the treatment of thoracic wounds lies in removal of respiratory obstructions, closure of injury to the thoracic wall, extensive use of early stage drainage of the closed

thoracic cavity to relieve compression therein, improvement of respiratory and circulatory functions and prevention of empyema. Open-chest techniques are limited to only those few wounded personnel who have either persistent, serious hemorrhaging within the thoracic cavity, or bronchial or esophageal damage.

Where there are abdonino-thoracic wounds, the thoracic cavity is also frequently treated conservatively with prompt drainage of the closed thoracic cavity. An exploratory laparotomy is then carried out on the abdominal portion and the diaphragm muscle is repaired from below.

C. Abdominal Wounds

Wounds that penetrate the abdomen frequently involve damage to the viscera in numerous places, loss of a great deal of blood and susceptibility to shock. Prior to and during the operation, a large volume of infusion is necessary. However, the amount of time that passes after resuscitation should not be too long. One must operate before two hours have passed or else the patient may relapse into shock. A prudent operating time is within 6 hours of injury. Wounds to the stomache and small intestine must be sutured. If the damage is severe, the damaged portion may be excised and anastomosized. For a colonic injury, the damaged section of the colon should be exteriorized or its perforations sutured, and a colostomy should be performed on its proximal end. Ligature should be performed to stop the bleeding of a mesenteric hemorrhage. If the liver is perforated, then it should be sutured or gelatin sponge tamponing should be used. Damage to the biliary ducts and bladder can be repaired. Serious damage to the gallbladder, spleen and a single kidney should be treated by excision.

D. Damage to the Spinal Cord and Extremities

During debridement, any foreign bodies or bone fragments must be removed from the canalis vertebralis, and the soft tissues should be sutured to recover the spinal cord and the canalis vertebralis. If the spinal cord is directly damaged, then treatment emphasis is on paraplegia. Fractures of the extremities at the front should be treated with a temporary traveling splint, and after operation should be fixed with a plaster or other therapeutic cast.

E. Multiple Wounds

These wounds are first judged as to the state of injury. The examination must be comprehensive to avoid at all cost the omission of major injuries. Treatment should be conducted sequentially according to the urgency of the condition of the wound. The three keys are to keep the respiratory tract unobstructed, control major hemorrhaging and supplement the blood volume.

12510
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DEVELOPMENT OF WASTE-FREE TECHNOLOGY URGED

Beijing ZHONGGUO HUANJING KEXUE [ENVIRONMENTAL SCIENCES IN CHINA] in Chinese No 2, 21 Apr 84 pp 26-28

[Article by Guo Zuyuan [6665 4371 3293], of Beijing Municipal Bureau of Environmental Protection: "Development of Waste-Free Technology Is the Orientation of the Present Industrial Revolution"]

[Excerpt] Introduction

After mankind's third industrial revolution social production and people's lives were greatly developed and improved. However, since the 1970's energy and environmental crises have appeared one after another in industrially developed nations. At present, a fourth industrial revolution is brewing in the world. Its primary components include the following items: the application of microelectronic computers, lasers and new synthetic materials; exploitation of nuclear, solar and other new energy sources; development of communication and space technologies; significant breakthroughs in genetic engineering--as a precursor to bioengineering research--and in oceanographic engineering. The strategic objectives of this industrial revolution can be summarized in ten points: (1) growth in industrial and agricultural production; (2) improvement of people's lives; (3) conservation of natural and energy resources; (4) reduction of labor intensity; (5) control of population scale; (6) safeguarding the health of the people' (7) enhancement of social welfare; (8) elimination of various sorts of waste; (9) protection of environmental purity; and (10) preservation of a sound ecology. The core of these stragegic objectives is the absolute optimization of economic, social and environmental benefits. Consequently, I believe that development of a waste-free technology is the orientation for the present industrial revolution. Whether they be microelectronic techniques, lasers, new synthetics, new energy sources, communications technology, space technolgoy, bioengineering or oceanographic engineering, all resources must be put into service to develop a new waste-free or minimal-waste technology, bring down the cost of natural and energy resources and enhance economic, social and environmental benefits.

The Trend of Development in China Toward A Waste-Free Technology

At the beginning of socialist construction in China, the Party Central Committee formulated a policy of urban and rural construction that "linked towns

to countryside and industry to agriculture, benefitted production and made life easier." Beginning in 1958, Chairman Mao and Premier Zhou issued appeals for the utilization of waste materials, and, in the effort to control pollution from the three wastes, at the end of the 1960s they successively directed us as follows: "Make multipurpose use of resources," "make multipurpose use of resources--there is always something more that we can do," "we must eliminate the three wastes--it is essential that we make multipurpose use of resources!" and "multipurpose use of resources ia a major problem and in this area we must resolve to surpass the rest of the world." In 1972 the Party Central Committee drafted a 32-word environmental protection policy that emphasized multipurpose use of resources and conversion of harmful substances into beneficial ones. In addition, the Chinese delegation to the United Nations' First Global Conference on the Human Environment announced this policy and reaped the profound praise and admiration of scientists from various nations. In 1973 China convened its First Conference on Environmental Protection, wherein experiences in multipurpose utilization and in elimination of harmful substances and promotion of beneficial ones in various localities were exchanged and criticisms were made of the wrong thinking that "making multipurpose use of resources brings neglect of one's proper duties." The state officially issued "Trial Industrial Discharge Standards for the Three Wastes," which explicitly directed us as follows: in accordance with environmental protection policies, "all industrial, mining and other enterprises must launch extensive technological reforms and technical innovations to eliminate the three wastes from the production process." "In order to transform the harmful into the beneficial and turn wastes into resources, they must strive to develop multipurpose uses for any of the three wastes that still must be discharged in the production process." Finally, "they must strengthen administration and reduce the volume of wastes discharged," and, "on any of the three wastes that cannot be utilized and that are harmful, purification treatments must be conducted and the wastes may not be discharged until they have come up to discharge standards." This shows clearly the orientation of China's economic construction and environmental protection work. In 1979 the state adopted the "Environmental Protection Law (trial)." In 1981 the State Council proposed 10 guiding principles of economic construction that reflected state economic readjustment, restructuring, reorganization and upgrading, and incorporated conservation of natural and energy resources and protection of the environment. In 1983 China convened its Second National Conference on Environmental Protection, wherein 10 years of experiences were summarized and environmental protection was affirmed as a fundamental national policy. In addition, it was proposed that economic construction, urban and rural construction and environmental construction must be planned, implemented and developed in synchrony to bring about an integration of economic, social and environmental benefits.

The above-related course of development in China's three major policies of urban and rural construction, environmental protection and economic construction, as well as the guiding ideology of three constructions, three synchronies and three benefits that was recently proposed explicitly by the State Council, amply illustrate that China is developing toward an industrial revolution that will feature waste-free technology to conserve natural and energy resources, expand production, improve lives and protect the ecological environment.

A Few Suggestions for China's Development of a Waste-Free Technology

China's first advocacy of multipurpose utilization of resources, conversion of the harmful into the beneficial and transformation of wastes into resources achieved initial success. However, due to the effects of the 10 years of disorder and obstruction, economic construction, urban and rural construction and environmental construction were coordinated neither with the government nor with each other, to the point that large quantities of natural and energy resources were wasted in industrial and agricultural production and in some domestic situations, and this waste brought about environmental pollution. The uprooting of disorder and return to rectitude that has occurred since the 3d Plenum of the 11th Party Central Committee has achieved great success. The 12th Party Congress of the Chinese Communist Party proposes that within this century, before we attain an uninterrupted increase in economic benefits, we must make a strong appeal for the quadrupling of production. Production must continue to expand, life must continue to improve, population must be controlled, waste must be eliminated and the environment must be protected. Economic construction, urban and rural construction and environmental construction must be planned, implemented and developed in synchrony, in accordance with the three major policies of economic construction, urban and rural construction and environmental protection. Additionally, we must strive to strengthen scientific research and develop a waste-free or minimal-waste technology. Only after these things have been accomplished can we attain the greatest economic, social and environmental benefits, assure the triumphant completion of China's socialist modernization and construction and make a contribution to the fourth global industrial revolution. To this end, I make the following suggestions for developing a waste-free technology:

1. Industrial and agricultural production and environmental protection sectors should summarize and exchange information on relevant production technology reforms, multipurpose use of production wastes and sponsorship of joint enterprises and recovery companies. They should improve the design plans, economic analyses, fundraising channels and popularization methods for the typical experience of economically, socially and environmentally beneficial waste-free or minimal-waste technology. In addition, they currently need to organize key suggestions for scientific research projects.

2. Urban and rural construction and environmental protection sectors should summarize and exchange information on relevant conservation of natural and energy resources. They should treat atmospheric and water pollution, control traffic noise, make multipurpose use of domestic wastes and sponsor coordination of specialties and recovery companies. They should improve the typical experience, economic analysis, fundraising channels and popularization methods for economically, socially and environmentally beneficial waste-free or minimal-waste technology. In addition, they currently need to organize key suggestions for scientific research projects.

3. Under the centralized leadership of the State Economic Council, the State Planning Commission and the Ministry of Urban and Rural Construction and Environmental Protection, we must work out a program for national economic construction. Regional, municipal, county and town planning and construction committees must then work out regional urban and rural construction programs

and corresponding waste utilization plans and municipal administrative and construction programs. The departments concerned must also establish in their localities various prototypes of newly built and rebuilt joint enterprises and joint farms utilizing waste-free or minimal-waste technology, as well as prototypes of residential areas that utilize waste materials and are clean and beautiful. Simultaneously, they should sponsor waste-free technology training classes and enhance propaganda and education, adivsory services and mastery of the work to increase production and practise economy, utilize waste materials and protect the environment.

4. Industrial, mining and other enterprises and their concerned departments must mobilize staff and workers to inspect the consumption indices for water, electricity and raw and processed materials in their own plants. They should contrast domestic advanced quotas with those overseas, uncover disparities and problems, research measures to catch up with and surpass the lower consumption quotas and implement those measures. They should then establish a comprehensive system of quality control and managerial responsibility and begin to institute reforms. In addition, to arouse initiative and creativity in all areas, they should provide appropriate awards in accordance with state regulations for advanced results with rationalization proposals, technological improvements and multipurpose use of the three wastes. Along other lines, in addition to rigorously instituting the three simultaneous efforts in enterprises and collecting fees for discharging pollution, in order to prevent waste and pollution the departments concerned must also formulate price-increase methods for those that exceed the various consumer standards for water, electricity and fuel use.

5. In accordance with the demands of expansion, each department concerned must consult developments overseas and enhance research into new energy sources, new materials, microelectronic technology, lasers, communications technology, bioengineering, oceanographic engineering, space engineering and other new technologies, and struggle to further develop waste-free or minimal-waste technology and economic, social and environmental benefits.

12510
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URBAN WATER POLLUTION CONTROL DISCUSSED

Beijing ZHONGGUO HUANJING KEXUE [ENVIRONMENTAL SCIENCES IN CHINA] in Chinese No 2, 21 Apr 84 pp 5-11

[Article by Wang Baozhen [3769 1405 4176], of the Harbin Architectural Institute: "Comprehensive Control of Urban Water Pollution"]

[Text] Pollution of China's urban water environment is already quite severe. Secondary tributaries in the urban water systems of large and medium cities have been extensively and seriously polluted and have become sewers. Most primary tributaries also have been polluted to varying degrees. Pollution belts and polluted sectors several tens of kilometers long have appeared along such large water systems as the Chang Jiang, the Huang He, the Zhu Jiang and the Songhua Jiang, that flow directly into the vicinities of large and medium cities or industrial and mining districts. According to the indications of a 1981 groundwater survey in 80 cities nationwide, all sites surveyed had been polluted to varying degrees. Despite efforts to prevent and treat water pollution in the past several years, particularly the considerable efforts made to control industrial waste water, especially since the First National Conference on Environmental Protection in 1974, the state of urban water pollution in China has not been brought under control and instead has continued to be aggravated. If we do not seek out and adopt more effective control measures, and if we continue to develop in this way, a water pollution crisis will arise and China's water resources, which are limited and daily in shorter supply, will suffer severe damage and destruction. In addition, sustained industrial and agricultural growth will be impeded.

China's urban water environment is severely polluted, and there are many reasons why this has not been brought under control. The primary reason is that too little money has been invested in water pollution control, particularly in city sewers and urban sewage collection and treatment facilities. For example, only 1.2 percent of urban sewage is treated, and the total treatment capacity of industrial waste-water treatment facilities amounts to approximately 15 percent of the total volume of industrial waste water. This means that the majority of sewage is not treated, but is discharged directly into nearby bodies of water and cannot help but give rise to serious pollution. In addition to this, the construction rate for urban regional comprehensive treatment facilities lags far behind the rate of increase in sewage

and pollutants, bringing about a year by year increase in the pollution load discharged into bodies of water. In the 30-plus years since the founding of the People's Republic, there has been continuous, endless debate over the technological route to urban sewage treatment in China. We have been unable to reach a common understanding, and this has made it difficult for the government to set policy and is a major cause of our lengthy hesitation.

Long-term practice here and abroad proves that there is a high degree of difficulty involved in the control of urban water pollution. No simple control measure, nor any construction of centralized, exclusively urban sewage treatment facilities, can completely resolve the problems, regardless of whether that measure employs conventional secondary treatment or whether it uses an oxidation pond or an on-land treatment and utilization system. We can control water pollution in an economically effective fashion only if we adopt comprehensive regional control measures.

At this time we will discuss thoroughly only a few major problems in water pollution treatment techniques and policies.

I. Resonable Exploitation of the Self-Purification Capacities of Bodies of Water, Determination of the Total Volume of Sewage Discharged by Various Cities and Formulation of Reasonable Discharge Standards

At present, the quality standards for discharged sewage that are in effect in China do not take into consideration the fact that the various bodies of water that receive sewage from nearby cities differ in size and in self-purification capacities. Unified discharge standards have been stipulated, such as 60mg/l of BOD, 100mg/l of COD and so forth. This arbitrarily uniform method is imprudent, and it is contradictory to water quality standards that are in effect for the various water grades in bodies of water.

Consequently, it is recommended that we change these arbitrarily uniform national discharge standards. Further, based on calculations of the self-purification capacities of the bodies of water receiving pollution from the various cities or industrial and mining districts, we should determine the total quantities of various pollutants discharged, and on that basis formulate discharge standards. To this end, we should augment investigation and research into the regular patterns of self-purification in bodies of water. The major ones are the pattern of hydraulic mixing and dilution; the pattern of natural biological oxidation and oxygen depletion/oxygen recorver; the patterns of migration and conversion of heavy metals, radionuclides and those organic pollutants that are not easily biodegradable; and particularly the pattern of aquatic food chain enrichment. Based on the many relevant parameters and measures and on ample data collection, we should push for an set up suitable mathematical models of the self-purification processes in bodies of water. We should also consider the water-quality standard of the major (that is, the highest quality) body of water downstream from a city to be the boundary condition and make the most accurate possible calculation of the self-purification capacities of its receiving waters. This should be used to determine the highest acceptable total pollution-discharge volume and to formulate corresponding discharge standards.

The largest permissible total volume for pollution discharge is based on the supposition that the entire flow of a body of water is involved in dilution and self-purification. However, in reality only a portion, or even a small portion, of the flow is involved in dilution and purification (particularly when discharge is practiced along the banks and shores of large rivers, lakes, reservoirs and bays). The reality is very different from the supposition. Consequently, we must consider appropriate revisions or inevitably we will make serious mistakes.

II. Economize on Water, Natural Resources and Energy Resources, Reduce the Total Volume of Waste Water and Accompanying Pollutants That Is Discharged

Because China's production technology and equipment are backward, and management is unsatisfactory, we waste a great deal of water, raw materials and energy. The result of this is that the volume of waste water and pollutants discharged per average unit produced or per average output value is several times or several tens of times higher than the advanced level of comparable industries overseas. For example, China must use 50～200 tons of water, averaging around 90 tons, for every ton of steel produced, whereas the advanced overseas level uses only 10 tons; China must use 400～600 tons of water for every ton of paper produced, whereas only 100 tons of water is used thus overseas; in China, the total suspended solids (TSS) and BOD discharged for every ton of product in the papermaking industry are 100～200 kg and 60～300 kg, respectively, as opposed to only 5～10 kg and 5～10 kg respectively, in America; in this country the total volumes of those same pollutants produced per ton of product in the tanning industry are 60～100 kg and 60～70 kg, respectively, as opposed to only 5～5.8 kg and 4～4.6 kg, respectively, in America. China's chlorine soda industry consumes 0.5 kg of mercury for every ton of caustic soda produced, whereas the advanced overseas level consumes only 3～5 kg of mercury. This enormous difference is on the order of several hundred times less.

According to statistics, for the past few years the total volume of polluted water has been in the process of increasing nationwide by an annual growth rate of 8 percent, a rate that is higher even than the growth rate in industrial production. If we do not adopt firm measures to save water and economize on raw materials and energy, by the end of the century the total volume of polluted water discharged will rise from the current level of 100 million tons/day to more than 400 million tons/day nationwide. This will bring about a situation wherein water pollution quadruples as production quadruples. When that time comes, our urban water environments will suffer extensively from the destructive effects of pollution and our natural water resources will be exhausted. Not only will it be difficult to continue to develop production, but even the lives of the people will be threatened. Consequently, we must do our utmost to avoid this disastrous effect.

At present, water is already in short supply in our cities. According to survey statistics from 220 cities, there is already a water shortage amounting to 12 million tons/day. Hereafter, urban water shortages will grow more serious day by day in the wake of economic growth. For this reason, we need to rely upon two paths to resolve the problem: We must increase our sources and

conserve on use. From a long-range viewpoint, exploiting new water sources is ever more difficult or even already impossible in some areas because there are fewer and fewer new water sources that can be exploited by our cities, particularly by the cities in the north where water shortages are severe. Consequently, we must emphasize conservation.

The primary reason for the alarming waste of water by industry is that the price of water is too low: it is far lower than actual value as reflected by the shortage of water resources. For this reason, we should substantially increase the price of water for industrial use. We should determine reasonable water-use quotas according to the current average advanced volume of water usage in various industries. We should install water meters in factories, workshops, sections of construction projects and major installations, and we should institute progressive controls to collect fees from those that use too much water and give awards to those that save water. We should also increase the rate of industrial water recycling and institute multiple use and multi-purpose use of the same water.

To reduce the volume of pollutants discharged in waste water, in the past we always placed an emphasis on treatment of industrial waste water. Furthermore, factories that discharged waste water, holding to the narrow policy of the "three simultaneous efforts" and the one-sided comprehension that "whoever pollutes must take responsibility" all had to construct waste-water treatment facilities. This simple reliance on after-the-fact treatment methods or on treatment at the drainage outlet is like attending to trifles to the neglect of essentials. It is a stupid move that wastes money and energy. The wise move to control industrial waste-water pollution should be aimed at the characteristic low utilization ratio of natural and energy resources in Chinese industrial production. The treatment emphasis should be placed on the production process; that is, administrative measures should be augmented through technical transformation, technological reform and equipment replacement. For example, there are already more than 100 factories in Jiangsu that through technical transformation have economized on, recovered or made multi-purpose use of natural and energy resources in the production process. They have achieved the major twin goals of eliminating (or alleviating) pollution and turning economic deficits into surpluses. According to estimates by the Ministry of Light Industry, technological reform and equipment replacement in five Chinese industries--papermaking, leather, refined sugar, synthetic fatty acids and synthetic detergents--would require an investment of approximately 2 billion yuan, and this might save or recover for China more than 3 billion yuan worth of natural and energy resources, eliminate 70$\sim$90 percent of the pollution and bring the level of the three wastes down to discharge standards. However, to carry out treatment after the fact (treatment facilities for the three wastes), would require us to invest a total of more than 4 billion yuan and also would require defrayment of enormous annual operating expenses of 600$\sim$700 million yuan.

In summary, the reasonable course for China in the control of industrial waste-water pollution is to emphasize elimination of most waste water and accompanying pollutants by economizing on, recovering or making multi-purpose use of natural and energy resources in the production process. When discharge

standards cannot be met they should be supplemented with the necessary wastewater treatment facilities. Increased natural and energy resource utilization ratios, decreased production costs and heightened economic results must be integrated with amelioration of pollution and promotion of environmental benefits.

III. Augment City Sewer Construction and As Quickly as Possible Increase Their Rate of Popular Use

Because China has long ignored city sewer construction, resulting in very backward sewer facilities in large and medium Chinese cities, the rate of popular use is universally quite low; even in the capital city of Beijing it is less than 40 percent. This is why it is difficult to collect all or most of a city's sewage and treat it or put it to use. At the same time, sewerless areas give rise to pollution of urban groundwater over a large area due to the dumping and sheet-flooding of sewage everywhere or through its discharge into seepage wells, seepage pits or ditches. This causes destruction and damage to groundwater sources and gives rise to the proliferation of waterborne contagious diseases. In addition, owing to toilet practices that splash sewage everywhere and cast a stench in all directions, sewerless districts and neighborhoods in large and medium Chinese cities have been brought to their current state of abominable environmental sanitation. On the other hand, because there are rather few sewers that currently accept excrement from flush toilets, the BOD value of sewage in the sewers of many Chinese cities is on the low side or is even too low. For example, it is around 100mg/l in the sewage of many sewers and in some it is only 50~60mg/l. At the same time, because the proportion of industrial waste water accepted is great and the corresponding content of organic compounds (COD) that are not easily biodegradable is quite high, thus lowering the specific value of BOD/COD, in some industrial cities this specific value is 0.3 or less. The content of nitrogen, phospherous and other nutritive substances is also small and the sewage becomes nonbiodegradable, so that the use of conventional biological treatment methods is ineffective. Consequently, we should stress the construction of sewers and as quickly as possible increase their rate of popular use.

IV. We Should Stress Centralized Treatment of City Sewage and Supplement This With Necessary Decentralized Treatment

In urban sewage treatment at the present time, various departments separately invest in their own self-administered industrial and mining enterprises or public agencies, and they construct small-scale sewage treatment plants that treat only the waste water from those units. From an economic standpoint, this is very unreasonable because, as the scale of treatment plants shrinks their unit capital-construction and operating costs increase. For example, the unit capital-construction cost of the small-scale secondary treatment plants of some factories is as high as 1,000 yuan/cubic meter/day. This is several times higher than the 200~300 yuan/cubic meter/day unit cost of large and medium urban sewage treatment plants (the above unit capital-construction costs do not incorporate state-of-the-art sludge treatment processes). Furthermore, due to the fact that the quantity and quality of water fluctuate widely in these plants and cause operational instability, in addition to which

they lack skilled, specialized technical personnel for operations and maintenance, the majority of them cannot maintain normal operation for long and cannot achieve the desired environmental results.

A more eocnomical and effective method is to arrange and coordinate the various sectors through unified planning among departments of environmental protection, and centralize the investments in the decentralized sewage treatment under a department or urban construction and environmental protection. Then we should pool resources to construct state-of-the-art urban sewers and large- and medium-scale regional sewage treatment plants in order to centralize treatment of mixed domestic sewage and industrial waste water. When waste water is discharged directly into city sewers, where it might cause corrosion or blockages and adversely influence sewage treatment and utilization, only then is there a need to carry out independent treatment within the plant. As far as possible we must particularly emphasize the achievement of closed circulation and reuse of non-biodegradable heavy metals and radioactive waste water. Thereby we will put a stop to their pollution of the environment, especially their migration, conversion and enrichment in the food chain.

V. Integration of Conventional Treatment Methods and Innovative Substitute Methods

China's territory is vast, and for different cities there are many different factors involved, such as geographical position and features, climate, weather, geology, proportion and composition of industry, amount of usable land and the quantity, composition and quality of water resources, energy resources and sewage. There is no single sewage treatment method that is universally applicable.

However, existing conventional treatment methods and oxidation pond and on-land treatment and utilization methods (sewage irrigation) all have their limitations and drawbacks and cannot completely control pollution of the water environment. As a result, we need to improve and enhance them and we should study, develop and popularize economical, energy-saving, effective sewage treatment techniques that conform to Chinese national conditions and that are exclusively Chinese in nature.

If we follow the pattern of urban sewage treatment developed abroad, and popularize conventional secondary treatment in our large and medium cities, then by the end of this century we should have constructed enough secondary sewage treatment plants to have a total treatment capacity of at least 100 million cubic meters/day. This total treatment capacity is only around 25 percent of the estimated national volume of sewage. Even if we work hard and condense this treatment capacity to 200 million tons of sewage per day, it will still represent only 50 percent of the total. We would need a total captial construction investment of approximately 40—50 billion yuan (the unit cost, including the capital construction cost of secondary treatment plants with state-of-the-art sludge treatment systems, is approximately 400 yuan (in southern areas) to 500 yuan (in northern areas). In addition, the yearly operation and maintenance costs would be approximately 4～5 billion yuan (about 10 percent of capital construction cost). This huge investment would be difficult for China, with her limited economic strength, to bear.

This kind of high-energy-consumption treatment facility might also meet with an energy supply crisis. For every cubic meter of sewage treated, about 0.3 kilowatt-hours of electricity would be consumed. Thus the treatment plants, with a combined treatment capacity of 100 million cubic meters/day, would need to consume 30 million kilowatt-hours of electricity. As a result we would need increased construction of power plants to produce an extra 1.5 kilowatts, and of coal mines to produce an extra annual yield of 5 - 6 million tons of coal (calculated based on a heat-generation value of 5,000 Kcal/kg). In addition, the construction of secondary treatment plants with a combined total treatment capacity of 100 million cubic meters/day would probably require the consumption of up to 10 million tons of cement and several million tons of steel. In their operation, the sewage pH-regulation, disinfection, sludge treatment and so on that require the consumption of large quantities of chemicals would consume several hundred thousand to several million tons/year of lime, acid, alkali, ferric sulphate, chlorine and so forth. In short, for the construction and correct operation of these sewage treatment plants, we would also need special new construction or extensions of cement plants, steel plants and chemical plants, as well as several plants to process sewage and sludge treatment equipment. These newly constructed or extended industrial and mining enterprises for "support" and "service" would not only require huge investment costs of up to 10 billion yuan, but could also produce a large quantity of new pollution. At the very least they would partly counteract the pollution eliminated by the sewage treatment plants. Therefore, from the perspective of overall environmental benefits, the results would be low.

In addition, conventional methods are limited with respect to the elimination of pollutants in sewage. They can only effectively eliminate the easily biodegradable organic substance (as expressed by BOD), and they have difficulty eliminating both the organic substances that are not easily biodegradabel (as expressed by COD), and the nutritive substances such as nitrogen and phospherous.

In brief, shortcomings such as exorbitant capital construction investment and operating costs, large consumption of energy and natural resources, production of other forms of pollution and limited elimination of pollutants make conventional secondary treatment difficult to popularize and apply extensively in China. However, in some large cities it is still necessary to adopt conventional secondary treatment methods when it is not appropriate to use oxidation pools or on-land treatment and utilization systems to treat and use the sewage because of factors such as land shortage or a complex sewage composition containing a lot of toxins or harmful substances. We should also further study and improve these methods and develop various techniques, such as those composed of treatments with anaerobic, facultative anaerobic and aerobic organisms, that are more economical, that save on energy and that can eliminate those nitrogen, phospherous and organic substances that are not easily biodegradable. Construction of conventional tertiary treatment and intermediate sewer systems is possibly economically worthwhile under conditions of severe water shortage in cities located either in areas without new water resources to be exploited, or where the exploitation of new water resources or the undertaking of water transport projects from a distance of several hundred kilometers is very uneconomical.

In China the use of oxidation pools and the treatment and usage of sewage on croplands has a long history and has been practiced extensively. For example, nationwide there are more than 100,000 mu of sewage fishponds and over 20 million mu of sewage-irrigated cropland, and they are expanding rapidly and showing great vitality. The most characteristic and advantageous point of difference in this respect between China and other countries is that through the establishment of artificial ecological systems for cultivating agricultural crops or aquatic plants, or for raising fish, ducks or geese, we not only conduct extensive treatment on sewage to rid it of pollutants but we also make effective use of it as a renewable resource. In this kind of artificial ecological system to dispose of and utilize sewage, three categories of organisms--decomposers, producers and consumers--cooperate to change the organic and nutritive substances in the sewage into final form as aquatic resources through decomposition, migration and conversion in the ecological system. Thus, this is also extremely effective in eliminating the BOD, COD, nitrogen, phosphorous, pathogens and other assorted pollutants in the sewage. Consequently, it is an effective secondary-plus-tertiary treatment method that is economical, saves energy and creates natural resources. The capital construction costs involved are only one-tenth to one-fifth of the amount needed for conventional secondary treatment plants of the same scale, and, due to the sizable income from aquatic products, operating costs are generally balanced by revenues and there may even be a profit. For example, a sewage fishpond in Changsha City produces 600 800 jin of fish per mu and makes a profit of 0.03 yuan for every cubic meter of sewage treated. By contrast, the conventional secondary treatment plant must disburse 0.15 yuan for every cubic meter of sewage it treats.

Another big advantage of this kind of ecological sewage treatment and utilization system is that it consumes no manpower and uses only solar energy. That is, it utilizes solar energy to irradiate the pond water, thereby accomplishing treatment and utilization of the sewage.

Despite the tremendous advantages demonstrated by China's ecological sewage treatment and utilization, many problems and defects remain. The most important of these are as follows: 1) End-product pollutants in the food chain also control the appropriate quantitative and proportional relationships between each trophic level in the food chain (web). This leads to an overabundance or shortage of certain or several links in the chain and makes it impossible to establish a satisfactory ecological balance, so that optimum results cannot be attained in either sewage treatment or sewage utilization. 2) Project facilities are too weak. For example, there is a widespread shortage of pretreatment projects, and this gives rise to sludge deposition in the forward portions of oxidation ponds, lack of flow due to the uneven distribution of water in the central portion and seepage from the bottom of ponds.

In order to overcome the above defects, we should adopt the following measures:

1. We must adopt effective in-plant treatment measures, resolutely prevent heavy metals and radioactivity from getting into the original sewage and reduce as far as possible the quantities of not-easily-biodegradable organic pollutants, petroleum, phenol, cyanogen and pathogens that get into the original sewage. This will prevent the pollution of aquatic and agricultural produce.

2. We must construct effective pretreatment facilities. Ideally these would be state-of-the-art primary treatment facilities, including grilles, depositing pools and settling pools. In addition, based on the specific original water quality and on the later particular water-quality requirements of the ecoloigcal treatment and utilization system, we can install other necessary treatment facilities such as regulating pools, oil-removal pools and so forth. Through interception, settlement and flotation treatments, we can effectively eliminate the suspended solids, oils and other floating substances, as well as the bacteria, viruses and parasite eggs in the original sewage. This will ensure the normal operation of the ecological treatment and usage system later on, and it will put into effect more effective treatment and utilization of of the sewage.

3. We must research and establish various appropriate technological processes for ecological sewage treatment and usage to suit local needs and water requirements. With respect to rather highly concentrated urban sewage or highly concentrated organic waste water, the following technological process may be adopted:

Pretreatment → anaerobic pool → facultative
anaerobic pool → aerobic pool → storage pool
(reservoir) → field irrigation

Sulphides porduced by anerobic degradation in the anaerobic pool can combine with remnant traces of heavy metals in the sewage to form an insoluble heavy-metal-supphide sediment and can thus be removed. In addition, some anaerobic bacteria and facultative anaerobic bacteria can effectively decompose several kinds of organic compounds that are not (using aerobic organisms) easily biodegradable, such as lignin and synthetic detergents, organic chlorine pesticides and nitrogenous compounds, and so forth. They can thereby effectively block the entry of the latter into the food chain of the later pond ecology.

In order to effect complete treatment and usage, we can adopt a multistage ecological treatment and usate system such as the following:

Pretreatment → (anaerobic pond) → facultative
anaerobic pond → fishpond → primary
(treatment)

By applying a sequency from duck- and geese-raising ponds to lotus ponds, reed ponds or field irrigation we not only can institute multistage exploitation and full utilization of sewage resources to reap bigger economic results, but we can simultaneously institute multistage, more complete and more thorough sewage treatment.

With respect to sewage irrigation, we must transform the uninspired practices of the past, in which we used sewage to irrigate only grain and vegetable crops, and determine suitable objects for irrigation according to the water quality of the sewage. We must set up a diversified ecological treatment and utilization system, and we may consider its use in irrigating nurseries,

ornamentals, forest belts and some economic crops such as cotton, hemp and so forth in the vicinities of cities, villages and towns. This will make a contribution to the beautification of the cities and the establishmetn of a satisfactory ecological environment.

VI. Intense Purification of Polluted Drinking Water Sources

Pollution of China's sources of drinking water is ever more extensive and severe. This is due to the continuous increase in the quantities of urban sewage, industrial waste water and accompanying pollutants that are discharged into bodies of water, and the simultaneous constant aggravation of the situation by nonspecific sources of pollution such as atmospheric sedimentation, precipitation and runoff from urban areas, industrial areas and agricultural fields. In some cities and industrial and mining areas where there is severe pollution of the drinking water, occurrences of various waterborne contagious diseases and cancers of the digestive tract have increased. Pollution control, elimination of pollutants from drinking water and protection of the people's health have become the major component parts of the comprehensive prevention and treatment of water pollution.

Pollution of the sources of drinking water cannot be completely eliminated simply by relying upon treatment of urban sewage and industrial waste water. This is because, in addition to the nonspecific pollution mentioned above, drinking-water sources also are the recipients of some nonspecific pollution that is even more difficult to control.

At present, the traditional water-purification technique in general use--"condensation of precipitation → sand filtration → chlorine injection for disinfection"--can only effectively eliminate turbidity and pathogenic bacteria, and cannot effectively eliminate the many soluble pollutants in the water. Since the beginning of 1970, when the Europeans and Americans began research and rapid development on techniques for eliminating pollution from drinking water, the Americans have primarily adopted a purification process that emphasizes filtration and adsorption through granular activated charcoal, whereas the Europeans have adopted ozone oxidization.

From the standpoint of safeguarding the health, lives and safety of the people, elimination of pollution from drinking water is a more direct method than is sewage treatment. The key juncture is control over the entrance of waterborne pollutants into the human body. We have lax control over specific sources of pollution such as urban sewage and industrial waste water, and particularly over nonspecific sources of pollution. Under these practical circumstances, and given the difficulty of altering this situation within a short period of time, it is essential that we establish a so-called "bioactivated-charcoal method" treatment process, combining ozone oxidation and adsorption through granular activated charcoal, in cities where drinking-water pollution is severe. The results of experimental research here and abroad prove that a system of pollution elimination that combines ozone and activated charcoal methods can be more effective in eliminating various pollutants than is the simple use of activated-charcoal treatment. The service life of the activated charcoal is notably lengthened, in general by 2 to 3 years, through the

following functions: the oxidation degradation of organic substances by ozone; the oxidation degradation of adsorped organic matter by ozone remaining in the activated-charcoal filtration bed; the provision of a rich oxygen environment for the bed of activated charcoal through decomposition and the consequent promotion of enhanced bioactivity on the surface of the activated charcoal; support provided by bioadsorption and oxidation degradation.

In the future we must continue to research and develop further techniques for eliminating pollution, such as high-gradient magnetic separation, reverse osmosis, ultrafiltration and so forth. This will enable us to select the most suitable purification methods and processes in accordance with the degree of pollution of the drinking water, the composition and quality of the pollution and the quantity of water treated.

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QUALITY OF GROUNDWATER IN CHINA ANALYZED

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[Article by Tian Chunsheng [3944 2504 5116], of the Institute of Hydrogeology and Engineering Geology, Academy of Geology: "A Preliminary Analysis of the Features and Trends of Groundwater Quality Variation in China"]

[Text] This article uses an environmental hydrogeological viewpoint to conduct a preliminary analysis of the features of deteriorating water quality and of the trend of variation in certain indices, both of which have appeared in China in the wake of urban water shortages, groundwater pollution and groundwater extraction and utilization. Criticisms and comments on inaccuracies are respectfully requested.

I. The Emergence and Effects of Urban Water Shortages

Water is both a precious natural resource and one of the essential elements in the human environment. Due to a lengthy period in which water use in production was ungoverned and water was squandered in domestic use, particularly in large cities where industry and population are concentrated, water needs already exceed natural resources. Cities are seriously short of water, the contradiction between water supply capacities and water needs becomes more prominent day by day and water-shortage problems have already appeared in some cities.

Because northern cities, which rely on groundwater as their major water source, have overextracted groundwater and drawn on static reserves, they have caused a decline in groundwater levels and a continuous expansion of funnels, and this has become one of the major environmental hydrogeological problems in the cities. For example, within a 200 square kilometer range of Beijing the pressure water head has fallen 22 meters, and within a 650 square kilometer range of Tianjin, descent funnels have formed and the water table has dropped 40 meters. In the city of Shenyang the range of groundwater descent funnels already nearly coincides with the area of the city proper and funnels are continuing to descend at a rate of 0.5~1 meter per year. In Xi'an, Taiyuan and other cities the water table has dropped by 40~50 meters. Cangzhou, Hebei and Changzhou, Jiangsu are among China's developing medium and small cities. Due to the overextraction of groundwater, they are also causing a drop in the water table over an extensive area. In Cangzhou the funnelled area already extends over more than 1,000 square kilometers.

Due to the drop in the water table, the thickness of the aquiclude is shrinking. For example, the water outputs of certain water resource districts in Beijing have been reduced by half when compared with those of 1959. In the eastern p tion of the city only 20~30 percent, or 40 percent maximum, of the original output can be obtained. According to statistics from 5 water districts in Shenyang, the volume of water extracted in 1977 was 89 percent of what was extracted in 1962, and in 1980 it was only 64 percent. If extraction continues at this rate, by the year 2000 the aquiclude in the northern extraction district may be dredged dry. China's famous Jinci Quan in Taiyuan and Baotu Quan in Jinan are both faced with the threat of becoming completely dried up because of overexploitation.

Due to the necessity of replacing water-intake equipment when the water table falls, consequent economic losses are severe. In Shenyang, extraction wells have been universally deepened to 60~80 meters, and some have been extended to 100 meters.

Forty percent of self-supplying water resources do not come up to the water output quota. The contradiciton implicit in industrial and agricultural water disputes has also occurred in some cities.

Even more serious, due to overextraction of groundwater and the drop in the water table, the osmotic concretion in the suspended soil layer becomes deformed and the water-bearing sand is compressed, producing earth subsidence. Earth Subsidence in Shanghai is something everyone is familiar with, and there it is primarily caused by the overextraction of groundwater. This has been verified with the initial results achieved by artifically refilling water into the ground. The range of earth subsidence in Tianjin is coincident with that of the secondary water-bearing funnels that orchestrate the drop in the water table. The period of greatest earth subsidence in Xi'an also coincided with the 1972~1978 period of sharp increase in the volume of groundwater extracted. The same kind of problem has also appeared in other cities such as Changzhou, Cangzhou, Luoyang and Taiyuan.

If we want to resolve the above-mentioned problems, we must first strengthen water resource management and be prudent in our extraction of groundwater. We must have the participation of geology departments in formulating plans for the exploitation and utilization of water resources. With respect to those cities that are seriously short of water, we must stress solutions to the problems of economizing on water usage and expanding water resources. With respect to those cities where the drop in the water table is so severe that earth subsidence has taken place, we must launch artificial refilling programs, protect the environment and safeguard normal industrial production and the health of the people.

II. Characteristics of Groundwater Pollution

A. The prominent features of groundwater pollution in China are concentrated in industrially developed, highly populated urban areas.

Due to the arbitrary discharge of both the "three industrial wastes" and domestic sewage in untreated form, the groundwater in some cities has been

extensively polluted. Some cities are more seriously polluted than others, but statistics from 50 large and medium cities reveal that 94 percent have experienced some degree of pollution. Of these, approximately 26 percent are severely polluted, about 48 percent are moderately polluted, around 20 percent are slightly polluted and there are only a very few cities that have water of satisfactory quality that has not been polluted.

B. Varieties and Distributions of Pollutants

1. The content of conventional components is universally rising, and, whether it is due to the influence of industrial, domestic or agricultural pollution, groundwater salinity is commonly increasing. The contents of components first reported as conventional components, such as sulphuric-acid radicals, chlorine ions, calcium, americium and other ions are notably rising, and the degree of mineralization has increased from 0.2 g/l to more than 2 g/l, polluting a broad area. In some areas the content of nitric-acid radicals is very high and the increase in the three nitrides is a major indication of the organic decomposition of substances in domestic pollution.

2. Phenol, cyanogen, arsenic, mercury, chromium and other toxic elements are quite widespread in some polluted cities, in addition to which certain other heavy metals and organic compounds appear, reflecting the pollution of groundwater by the "three industrial wastes." With the exception of the phenols and cyanide, the spacial and chronological distribution of these substances in the groundwater is generally quite stable. Their area of distribution is never very large and their rate of detection is not high, but when they are detected in wells they always greatly exceed the detection rate and exceed the standard by a large multiple.

Furthermore, in the vicinity of a polluted well there is certain to be some corresponding source of factory pollution. The concentration and the time of pollutant detection is always intimately associated with the discharge from the pollution source.

In addition, certain individual pollutants are quite significant in the pollution of certain cities, for example there is cadmium pollution in Shenyang and flourine pollution in Baotou, Tianjin and Nantong. The organic phosphorous pollution of Beijing and Shijiazhuang, the nitro-compound pollution of Liaoyang and Anshan and the petrochemical polution of Lanzhou, Jinzhou and Jilin all reflect the characteristics of industrial groundwater pollution.

C. Urban Groundwater Pollution and the Environmental Hydrogeological Conditions of the Location Are Closely Related

Because groundwater lies hidden in the earth, the causes and extent of pollution and the range of its distribution are determined by the environmental hydrogeological conditions of the city location.

A division of Chinese cities according to the environmental hydrogeological characteristics of the localities is as follows: 1) Cities on alluvial and pluvial plains anterior to mountains, such as Beijing, Shenyang, Baotou and

Shijiazhuang; 2) Cities on river terraces or in intermontane valleys, such as Harbin, Zhengzhou, Nanjing, Wuhan Chongqing, Xi'an and so forth; 3) Coastal cities, such as Guangzhou, Shanghai, Dalian, Qingdao and Tianjin; 4) Cities in karst areas such as Nanning Liuzhou, Guilin, Guiyang, Jinan, Taiyuan and so forth; 5) Inland cities such as Urumqi.

The hydrogeographic conditions differ among the various types and the hydrogeographic problems each have their own distinguishing features. In protecting groundwater resources we must deal with each case on its merits in accordance with the characteristics of the above-listed different environmental hydrogeographic types, and we must adopt control measures based on local conditions.

D. The primary reasons for groundwater pollution are as follows: industrial and domestic sewage is discharged into the ground through various channels, particularly seepage pits and seepage wells, and consequently pollutes the groundwater; industrial waste residues and urban refuse is leached by rainfall and seeps into the ground; the protective belt around water resources is unsatisfactory; there is imprudent sewage irrigation and long-term use of agricultural pesticides and chemical fertilizers; there are man-made factors in the pollution process (artificial refilling, seepage next to wells, overextraction or underground engineering projects and so on). All of these can lead to groundwater pollution.

III. An Analysis of the Changing Trends of Certain Groundwater Components

A. The Problem of Hardening Groundwater

Groundwater hardness is an important index of water quality. Particularly in polluted areas, it is a direct and indirect index of the state of pollution expansion.

At present, increased groundwater hardness is a widespread problem in large, medium and small Chinese cities alike, and there is also a rising trend year after year. This has become a major feature of variation in urban groundwater quality. For example, the area of Beijing within which groundwater exceeds hardness standards (this refers to drinking-water standards, here and below) amounts to 208 square kilometers. Those cities in which groundwater hardness exceeds standards by more than 50 percent include Beijing, Shanghai, Tianjin, Shenyang, Baotou, Jilin, Wuhan, Dalian and Urumqi. In Taiyuan, Xi'an and Nantong the problem is also very serious.

The result of our computations of historical data on the 11 wells in 7 Shenyang municipal water districts, beginning with the year 1957, indicated that groundwater hardness has increased by an average of 0.4 German degrees per year. In 1957 the hardness averaged 10 German degrees. In 1975 it has increased to 17 German degrees and there were 2 wells that had exceeded standards. Forecasting to 1985, the average hardness will increase to 21 German degrees and 3 wells will have exceeded standards. By 1995 the average hardness will exceed standards, having reached 26 German degrees, and 5--or 46 percent--of the wells will have exceeded standards. We should keep a close eye on this developmental trend.

The increase in groundwater hardness is generally associated with groundwater mineralization in the region, regional environmental pollution and various other factors. Calcium and magnesium ions exist extensively in nature, and these are also major nutritive elements for animals and plants. In a certain environment, sodium and ammonium ions in the water can replace the calcium and magnesium ions adsorbed into the soil and rock surfaces, and this is the primary mechanism of groundwater hardening. Owing to the increase of water hardness brought about by industrial pollution, permanent hardness becomes predominant. Because the environment is polluted, all sorts of salts enter the ground. Sulfation, carbonation and nitrification of the ground occurs and causes large quantities of sodium or ammonium ions to displace the calcium and magnesium ions adsorbed into the soil. Consequently, permanent hardness increases. Domestic urban sewage, refuse and carbon dioxide produced through biodegradation can also promote increased carbonate hardening of groundwater. This was particularly evident in some of the ancient cities in history. In addition, sewage irrigation causes various saline pollutants, especially nitrate salts, to seep into the ground. This also creates the above conditions for ion exchange, causing a rise in groundwater hardness. In short, modern industrial pollution, longstanding historic domestic pollution and various salts seep into the ground, promote ion transfer between salts in the groundwater and cause calcium and magnesium ions to increase year after year, becoming a clear index of polluted regions. This has become one of the prominent features of variation in urban groundwater quality in China.

B. Nitrogen Pollution of Groundwater

Nitric acid radicals, nitrous acid radicals and ammonia are usually called "the three nitrates." When nitric acid and nitrous acid exist in the groundwater it is an indication that the groundwater is receiving bioorganic pollution. When there is ammonia present, it illustrates that there are both historic pollution and current, new pollution. An increasing nitrate content in urban groundwater is also a widespread phenomenon in China. These nitrates usually come from industrial exhausts that are dissolved in rainwater and fog and then enter the soil, from organic substances in industrial and domestic sewage that decompose and enter the soil as nitrates and from the decomposition of fertilizers and organic matter in the soil. From this it can be seen that nitrogen pollution is primarily the result of human activities. This is particularly obvious in areas of concentrated residence or the core districts of historic cities. Consequently, nitrates have been detected in large, medium and small cities alike. The large cities include Beijing, Shanghai, Shenyang, Xi'an, Nanjing, Tiayuan, Hohhot, Changchun, Jilin, Harbin and Chengdu. Medium cities include Ningbo, Wenzhou, Yinchuan, Handan and Baoding. Small county seats, villages and small towns in Henan, Shaanxi, Shandong and Jilin have all reported nitrates. In these cities, particularly Jilin, Yinchuan, Wenzhou and Guiyang, which are the most gravely polluted of them, the nitrate levels nearly all exceed standards by more than half.

In order to solve nitrate pollution, we must first as quickly as possible establish and perfect a network system of urban sewage discharge pipes, strictly forbid sewage discharge into seepage pits and seepage wells and satisfactorily control urban refuse and sewage. Second, we must set up groundwater source

protection zones, within which refuse disposal and sewage irrigation are prohibited. In agriculture we must make prudent use of chemical fertilizers and pesticides and set up reasonable regulations and quotas for sewage irrigation. We must also pay close attention to urban sewage treatment and prevent nitrates in industrial sewage from getting into the ground and polluting the groundwater. Because nitrate groundwater (also called rich water) is very rich, we may also collect it for use in agricultural irrigation. In this way we would treat groundwater and also carry out multipurpose utilization.

IV. The Problem of Groundwater Fluorine Enrichment

Enrichment of groundwater fluorine is also a problem of environmental hydrogeology in many cities and regions. In most cases this is part of the primary environment, namely, natural enrichment of groundwater fluorine. For example, fluorosis-induced endemic ailments that are widely dispersed over the Northeast, North China, and Northwest and the Southwest all have a certain association with natural fluorine enrichment. However, in some cities problems have also appeared in the secondary environment, occurring in the process of human exploitation of groundwater. High-fluorine regions created due to industrial pollution, such as in Tianjin, Baotou, Taiyuan, Nantong and other cities, have both natural groundwater fluorine enrichment and man-made fluorine pollution. The groundwater fluorine in some cities exceeds standards by more than 50 percent. Here we will conduct a brief analysis and discussion of the conditions of fluorine enrichment.

A. The Geochemical Properties of Fluorine

Fluorine is a nonmetallic element belonging to the halogen family, and it is also one of the trace elements essential to the human body. Its chemical properties are very reactive: it can combine with many elements to form the chemical compounds found most widely distributed in the earth's crust, such as hydrogen fluoride, calcium fluoride, magnesium fluoride, silicon tetrafluoride and so on, and it is present in silicate and phosphate. Under conditions of acidity, fluorides often are present in the form of complex compounds. Under alkaline conditions, fluorides are mobile in the form of ions (F-1). In the natural world fluorides are often present in the form of complex compounds. The major fluoride-bearing minerals include fluorite, cryolite, topaz, apatite, fluorapitite, biotite, amphibole, and tourmaline. Therefore, the fluoride-bearing geologic forms--acidic igneous rock, metamorphic rock and sedimentary rock that contain the above minerals--thus become the sources of substances that enrich groundwater fluorine.

B. The Hydrogeochemical Properties of Fluorine

After weathering, the above complex fluorine compounds can release fluorine in the water, resulting in highly soluble fluorides. The ability of the fluorine to dissolve in water depends upon the solubility of the chemical compound. Fluoirne has the smallest radium of all the halogen ions, and in acidic or neutral water it forms stable chemical compounds with other elements that have relatively small radii, such as calcium, magnesium, aluminum and iron. Of these compounds, ferric fluoride is the most soluble. Consequently,

fluorine-bearing aluminosilicate is the primary source of groundwater fluorine. The influence of groundwater calcium and soidum elements on fluorine has a bearing on the solubility products of calcium fluoride and sodium fluoride. At a temperature of 20 degrees C the solubility of calcium fluoride is 16 mg/1. Endemic fluorine ailments are often restricted by the proportion of fluorine to calcium ($\gamma F/\gamma Ca$ ion activity). In alkaline, sodium bicarbonate-type water, the fluorine interacts with sodium to form highly soluble sodium fluoride, with a solubility of 40,000mg/1, and is present in the water in an ionic form that is also highly stable. Summarizing the above, the degree of fluorine enrichment in water is dependent upon the mineralization, chemical composition, temperature, pH value and silicic acid content of the water, as well as the geochemical properties of the lithofacies of the water-bearing rock. Therefore, in deep groundwater, a moderately mineralized alkaline, sodium bicorbonate-type water is conducive to the migration and enrichment of fluorine ions.

C. The Influences of Hydrogeologic Conditions and Climate

With respect to regional distribution, high-fluorine areas often appear in the zones of smooth terrain that occur on the front edges of diluvial fans, downstream from alluvial plains and on the margins of basic centers. The water in these regions alternates slowly, and there is also a tendency, as the vertical depth increases and the alternating action of the water slows, for the fluorine content to rise. Because the alternation of the water is slow, on the one hand the groundwater is able to dissovle the fluorides in the medium completely. On the other hand the alternating action of the positive ions is enhanced and sodium ions replace the calcium ions in the water, and, as a result, a large transference of soidum fluoride can form in the water. In arid and semiarid regions, because the climate is blazing hot and the volume of rain is relatively small, there is intense evaporation of groundwater, the degree of mineralization is quite high and conditions advantageous to fluorine enrichment are created. It has been asserted that the highest fluorine content is produced in water with a mineral content of 600~900mg/1. When the degree of mineralization continues to increase beyond this range it leads to certain reductions in fluorine content.

The western regions of Jilin and Liaoning, the forward edge of the diluvial fan in front of Baotoushan in Nei Mongol, the eastern portion of the North China Plain, the central portions of the several large basins in Shanxi and the southwestern peripheral zone of Xinjiang's Zhunher Basin all have the above environmental hydrogeological and climatic conditions. Extensive high-fluorine regions have appeared in all of them.

In addition, the geologic structure has a certain influence on fluorine enrichment. Abyssal faults are frequently the passageways for fluoirne enrichment. For example, along the Jinpu Railroad line in Cangzhou District the groundwater has been influenced by an abyssal fault and the stripped fluorine content of the groundwater has risen. The fluorine content of Tianjin's underground hotsprings has increased as well. These instances illustrate the relationship between fluoirne and geological structure.

Research into the patterns of groundwater fluorine enrichment and migration is of major significance in water modification for illness prevention. In regions having both natural fluorine enrichment and man-made environmental pollution we must attend closely to research on the mechanisms of fluorine migration. With respect to their effects on groundwater fluorine, we must distinguish between the factor of natural enrichment and that of man-made pollution. Only then will we be able to indicate the proper control measures. First we must emphasize regional water modification, and later we should stress control of the sources of pollution to prevent pollution of the groundwater.

In addition to endemic fluorine illnesses, there are also other endemic diseases in China, such as Keshan disease and osteoarthritis deformans that are distributed over 14 Chinese provinces and the regional hepatic and esophageal cancers in certain local areas. At present, numerous environmental medical workers and environmental hydrogeological workers are researching these diseases and there are several hypotheses and debates concerning their etiologies. However, several research results and achievements in water modification indicate that these endemic diseases are intimately associated with environmental hydrogeological conditions. Consequently, intensive research into the association of environmental hydrogeological properties in these regions with human physical health is of major importance in controlling and taking precautions against expansion of the disease areas.

12510
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SPECIAL-PERMIT MANAGEMENT LAW CONSIDERED

Beijing ZHONGGUO HUANJING KEXUE [ENVIRONMENTAL SCIENCES IN CHINA] in Chinese No 2, 21 Apr 84 pp 29-32

[Article by Shen Xin [3088 9515], of Plant 3653 of the Ministry of Space Industry: "A Trial Discussion of the Implementation of a Special-Permit Management Law"]

[Text] Since 1979, when China promulgated its Environmental Protection Law, there have been laws to follow in environmental management, a management mechanism has been progressively established and perfected and a satisfactory state of affairs has emerged. However, one problem remains: in the process of execution and implementation, statutes under the Environmental Protection Law are far less effective than are other laws. The environmental protection mechanism for "implementing and supervising the execution of state principles, policies, statutes and decrees concerned with environmental protection" is in a weak and ineffectual condition. Usually it is only when a major pollution mishap has occurred and popular indignation has been aroused that it cooperates with the departments concerned to handle the matter. Although there are explicit provisions for the investigation of polluting enterprises and public agencies and for the execution of the "three simultaneous efforts," there is no legal procedure for carrying out these provisions and it is difficult to strictly enforce them. Thus, old sources of pollution have not yet been treated satisfactorily and new sources of pollution continue to proliferate. We have lost the capacity to control polluting enterprises and facilities on our own. In view of these facts, I have examined seven cities, counties and towns in four provinces, and consulted data on overseas environmental management methods from Japan, America and England. I have studied relevant Chinese laws, institutions and management structure with respect to industrial and commercial management, foodstuffs sanitation management, transport management and so forth. Linking China's national condition with the existing state of environmental management, I propose that, relying on environmental law and the relevant statutes, decrees and institutions, we should put into practice a special-permit management law to allow exceptional enterprise operation and production by enterprises and public agencies in polluted environments. I provide here the references and discussion on the areas concerned.

I. The Necessity of Instituting a Special-Permit Management Law in China

The various production activities that act to pollute and damage the environment in varying degrees do so at the same time as they produce for society

the commodities needed to sustain human life and development. Those economic activities that are socialist in nature are the ones that can best satisfy the demands of the people for uninterupted growth in their material and cultural lives, and actions therein that endanger the interests and health of the broad masses of people are not permitted. Hence, the Environmental Protection Law explicitly provides that "the address, design, construction and production of all enterprises and facilities must attend fully to the prevention of environmental pollution and destruction." Therefore, the various production activities of enterprises and public agencies must be socially necessary and also conform to the precondition the fact that they do not cause environmental pollution and destruction. Thus there is a difference between polluting and nonpolluting production activities. Special-permit management law will distinguish between the two, and under specificied conditions only, it will allow polluting production activities to be carried on and install corresponding organizations authorized to manage them. Enforcement mechanism exist alike in traffic control, where there are traffic police and public jails, in food sanitation control, where there are inspection stations and quarantine stations, and in industrial and commercial management, where there are industrial and commercial management institutes. Consequently, a special-permit management law is an anti-pollution environmental management law determined by the Chinese Environmental Protection Law, and it is an indispensable method of using the law to treat pollution.

In the economic system in effect in China, as far as ownership is concerned, there are three forms: ownership by all the people, collective ownership and individual ownership. People-owned enterprises and public agencies that engaged in polluting activities originally could be handled in accordance with the Six Articles of Environmental Protection. However, in the existing economic structure there are two routes: the route taken by central enterprises and that taken by local enterprises. In a new building project, the office responsible for local enterprise tends to consider approval from an economic angle. The procedure in effect for examination and approval often does not go through the department of environmental protection. so the local enterprise can just take the money and start the project. However, a central enterprise does not need local examination and approval; the department responsible sets the plan and more often than not there is no necessary procedure for environmental protection organizations to participate in the approval process. In the past few years, except for a few key construction projects that were carried out in strict accordance with the Environmental Protection Law, all other projects treated the Environmental Protection Law as a mere formality. For example, in a country near Hangzhou there were nine projects begun between 1982 and 1983. Of the seven that are already in operation, four have serious pollution problems, yet none have been investigated by the Department of Environmental Protection. A few enterprises in Zhongqing County, Sichuan, initiated four projects between 1981 and 1983; all of them have polluted the environment and none of them have undergone Environmental Protection Department procedures for examination and approval. Environmental management and prevention of pollution benefit all of society, and the provisions of the Environmental Protection Law also are completely proper. However, because there are many routes and aspects involved in the execution of these provisions, there is no authority mechanism that can be specifically

brought to bear, and thus the enforcement procedure cannot be carried out. Implementation of a special-permit management law will provide enforcement mechanisms and procedures to ensure that the Environmental Protection Law is carried through and executed.

Looking again at the various kinds of collectively owned and individually owned, jointly managed enterprises, they all raise their own funds, do their own planning and then begin their projects. For some, there are offices responsible for the work (such as the two light industry offices in every locality), and others rely instead on commune of team management, or even joint operation by several families. Still others cannot operate legally without a business license from the industrial and commercial management office. Finally, some appear as sidelines, where no procedure is required. When a project is initiated, there is never any requirement that the Department of Environmental Protection should take an interest in it. These enterprises represent a very large proportion of the proliferation of new sources of pollution in the past few years. In addition, as the present environmental protection management work in large cities is strengthened, some enterprises will adopt joint management forms or will act as firms that contract out for industrial production in order to diffuse their polluting factories into medium and small cities and even the broad countryside. For example, the Hangzhou Electroplating Plant diffused its Paoguang Electroplating Plant out to a few production teams in the scenic area next to Xi Hu, causing pollution of the air and water in Xi Hu Scenic Area. Certain Shanghai factories (such as bicycle plants) have diffused pollution out into Tonglu County in Zhejiang and Beijing has diffused it to various counties in Hebei. These polluting enterprises, whether production teams (representing 60~70 percent) or communes are in charge, can thus just start up their projects. There are absolutely no "three simultaneous efforts" procedures and the state of environmental pollution is extremely grave. For example, several households jointly operating a papermaking plant in a production team in Guizhou mountain area illegally bought up bamboo from the area all around and destroyed the mountain forest. The waste liquid from the papermaking process was wantonly discharged into the Jiang He, and for as far as the Lijia River Bend section 42 kilometers away, foam floated on the surface, the water was blackened and no aquatic animals lived in the river. Enterprises like this are distributed in large numbers all over the country, causing serious pollution and yet existing in an unsupervised state. If we target this complex, polluting enterprise structure and implement a special-permit management law, we will distinguish these polluting enterprises from ordinary enterprises. By forcing the addition of environmental protection regulations to the general enterprise and public agency management laws, we will bestow compelling restrictions on those polluting enterprises that jeopardize the interests and health of the people at large.

II. Implementation of a Special-Permit Management Law Opens Up a New Aspect of Environmental Management

With respect to industrial pollution, environmental management techniques so far have developed from treatment of the sources of pollution to regional control. China's environmental protection work has defined comprehensive planning,

rational distribution, multipurpose use, transformation of the harmful into the beneficial, reliance on the masses, mass participation in the work, protection of the environment and conferral of benefit on the people as the policies that reflect comprehensive management. However, the proliferation of polluting enterprises such as exists today is certainly not controlled by these policies, rather it is determined by the respective indidivuals in charge. Environmental protection organizations only remain in control of the "three simultaneous efforts" (and even this is not firmly controlled). Comprehensive planning, rational distribution and multipurpose use are all difficult to carry out. If we implement a special-permit management law we can turn the current passive management into active management: issuing a special permit under the guidance of comprehensive planning and rational distribution will also create the necessary conditions for multipurpose use and for transformation of the harmful into the beneficial. For example, through multipurpose use the waste gas in the iron and steel industry can be used to make acid, which can both treat the gas pollution from the iron and steel enterprises and eliminate specialized acid-making plants. Through the power to issue special permits, we can prevent the establishment of new sources of pollution in large cities, in areas of concentrated population and in scenic and historic spots, and we can also outlaw the sites of pollution that already exist. The implementation of a special-permit management law can resolve the following problems and open up a new aspect of environmental management.

1. Environmental protection organizations can rely upon the relevant statutes, decrees and institutions to proceed from comprehensive planning, rational distribution and regional comprehensive treatment to use the issuance of special permits as a measure to control the unplanned and unchecked proliferation of new polluting enterprises--particularly those which are privately funded and outside the national plan.

2. By passing a special-permit management law we can take preventive measures before pollution is produced. No enterprise or public agency lacking a special permit can engage in polluting production activities. This will thereby transform the current passive management situation in which we treat the symptoms but not the disease, and break us free from the existing passive state wherein we stress management only after pollution has occurred.

3. By passing a special-permit management law we will separate research from management in environmental protection organizations, and thus we can concentrate more forces on relevant environmental protection research. This can also change environmental protection management into a specialized field of management. This will enable us to enhance and develop both research and management in environmental protection and to surmount the current state of confusion in some environmental protection organizations.

4. By passing a special-permit management law we can avoid unnecessarily building any more polluting enterprises. We can also compress the scale of capital construction, increase the production efficiency of enterprises that already have a treatment capacity and cut down on expenses for the state. In addition, we can play a role in readjusting the balance between enterprises that have a treatment capacity, which have higher costs because they treat the three wastes, and enterprises that have no treatment capacity, which sacrifice the environment for the sake of profits.

5. By passing a special-permit management law we can get environmental protection work onto the right track of planned management, where it will be clear how things stand. Through registering and approving special permits for polluting enterprises, on the one hand we can get overall control of the total situation in order to bring environmental protection management into line with plans and law a foundation for comprehensive pollution monitoring. On the other hand, we can provide a reliable analytical basis for regional treatment.

6. Passage of a special-permit management law will be beneficial to implementation to the system in effect for established enterprises, in which there is a deadline for controlling pollution and fees are charged for discharging pollution. It will change the current passive situation, in which enterprises discharging pollution refuse or delay payment of discharge fees and there is no authoritative countermeasure available. On the basis of the special-permit management law, only a temporary permit should be issued within the time deadline for control, and a discharge fee should be imposed. Those that fail to control the pollution within the time limit or refuse to pay the discharge fee will have their special permits revoked. Lawful enterprise production will become unlawful and a production halt will be required in order to promote control.

7. Environmental protection work is work with a strong social character. If we adopt a divide and rule approach our forces are dispersed and management seems weak and ineffectual. If we implement a special-permit management law and carry out centralized management through a management mechanism with central authority, this will make for consistent enforcement, unified standards, responsibility in management, direction in conduct, and convenient cooperation. If there is a centralized procedure for examination and approval it will eliminate the occurrence of irresponsible approvals by some enterprises that consider only the interests of a small group and that thus harm society's interests.

8. A special-permit management law will benefit multipurpose use and rational distribution of water resources and it will effectively protect water resources from pollution. It will also be beneficial to the job of protecting scenic and historic sites, tourist excursion spots and areas of concentrated population, preventing the appearance of polluted sites within them.

10. A special-permit mamangement law can bring the self-purification capacity of the environment into full play and make scientific use of it, reducing the cost of pollution treatment. For example, if we set up a large-scale animal husbandry enterprise or a primary food-processing plant in a mountain area, waste residues and liquids can be directly converted and used as fertilizers. But if we establish the same kind of enterprise in a large city we will cause a lot of pollution and waste a large quantity of natural resources.

11. A special-permit management law will be beneficial in bringing the whole people into participation in environmental management. It will correctly reflect and resolve the issue of environmental pollution, satisfy the various reasonable demands of the masses for environmental protection and outlaw all improper sources of pollution.

III. The Organization of a Special-Permit Management Law

It is through a specific enforcement organization that a special-permit management law will bear responsibility for "implementing and supervising the execution of state principles, policies, statutes and decrees concerned with environmental protection (Environmental Protection Law, Section 4, Article 26)," and the law will be a component part of environmental management. The administration and business of this organization will be led by the environmental protection organizations of each respective locality. However, when considering some questions of regional river planning that are of concern to the nation as a whole, localities must also consider questions of unified national policy and therefore they must accept ministry leadership. Below the provincial level, the counties need only to set up special-permit posts or stations under the leadership of the provincial environmental protection bureau. Their specific job will be to manage and enforce the special-permit management law: they will issue and revoke special permits, issue temporary special permits and impose pollution discharge fees on established enterprises; they will penalize unlawful enterprises and public agencies and reward advanced environmental protection units; they will carry on supervision and management of units that discharge pollution and impose management fees upon them.

IV. Basic Components of a Special-Permit Management Law

1. The examination and approval of "environmental impact reports" (prescribed standard forms to fill out) in accordance with environmental protection law.

2. The checking and acceptance of the "three simultaneous efforts" projects.

3. The implementation of centralized planning and rational distribution of polluting enterprises, and the issuance of special permits in accordance with environmental capacity and the relevant provisions of the Natural Conservation Law (decisions on the detailed rules and regulations for the conditions of approval to be based on the Environmental Protection Law and relevant statues, decrees and institutions).

4. Withdrawal of the special permits of those units that have obtained them but have continued to exceed discharge standards, or the handling of those enterprises and public agencies not in compliance with the Environmental Protection Law (for example, imposing fines, halting production for renovation, setting deadlines for pollution control, imposing pollution discharge fees and so forth).

7. Compilation of relevant regional environmental protection data and analysis of the state of environmental quality in the area to provide firsthand data for environmental planning and scientific research. Participation in the formulation and implementation of environmental planning.

8. Organization of the units concerned (such as monitoring stations, head offices, environmental protection bureaus) to conduct regular or irregualr inspections of environmental protection work at polluting enterprises and public agencies.

9. Participation in the investigation and handling of environmental pollution mishaps and specific implementation of the resulting conclusions.

V. Approval Procedures for Special Permits

The applications submitted by polluting enterprises and public agencies, as well as their environmental impact reports, should be submitted to the special-permit management posts for examination and approval, and a copy should be handed in to the environmental protection bureau at the same time. Within a certain time period, the special-permit management post will organize the units concerned to conduct the examination and approval. The environmental protection bureau will be held responsible for technical appraisal and for the job of technical examination and approval of regional planning (the special-permit management post will be responsible for organiziang the work). If the appraisal indicates that everything is up to standard and a certificate to that effect is signed and issued, the enterprise may carry out the design and construction. Prior to the beginning of operation, the enterprise must put forward a "three simultaneous efforts" acceptance report and the special-permit management post must organize the personnel concerned to carry out the checking and acceptance. Those that meet the standards will be issued a special permit and will at once become lawful production units.

When established enterprises apply for temporary special permits, in addition to submitting an environmental impact report, they must also submit a report on the program to effect pollution control within the deadline. If appraisal standards are met, a temporary special permit will be issued immediately, but if they are not up to standard a discharge fee will be collected for postponing control. Those which undergo three inspections without meeting standards will then be forced to cease production and a deadline will be set for pollution control.

VI. A Number of Problems That Need To Be Resolved in the Implementation of a Special-Permit Management Law

1. System reform: In the implementation of a special-permit management law, the environmental management mechanism must be separated from and independent of the existing environmental protection mechanism, acting as an enforcement mechanism for environmental management.

2. Funding problems: A portion of the funds can be disbursed from management fees paid by special-permit enterprises. The remainder will require other sources of funding.

3. Problems of overlap between special-permit management work and judicial or public finance concerns must await resolution.

4. We must formulate relevant instruments for the enforcement of a special-permit management law, such as special-permit enterprise regulations, a special-permit management system, relevant ordinances for rewards and punishments and so forth, and these must be passed by the departments and conferences concerned.

5. A special-permit management law would destroy the enterprise leadership relationships that had originally existed in environmental protection work, and the enterprise's environmental protection organization would take over dual leadership of the office originally responsible for the work and also the special-permit management post. Consequently, a few problems would have to be resolved. A great many enterprises jointly operated by collectives and individuals have practically nobody to manage environmental protection work, and the establishment of leadership relationships also poses a few problems that await resolution. The establishment of an authority mechanism requires the strong support of every sector of society. How to obtain passage through the government apparatus in order to set up this new mechanism also presents a few problems that must await resolution.

12510
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IDEAS ON RESTORING HUANGQI LAKE DISCUSSED

Beijing ZHONGGUO HUANJING KEXUE [ENVIRONMENTAL SCIENCES IN CHINA] in Chinese No 2, 21 Apr 84 pp 77-79

[Article by Gong Yicheng [7895 4135 2052], of Ulanqab League Bureau of Environmental Protection, Nei Mongol: "Some Suggestions for Gaining Control of Huangqi Lake"]

[Text] I. A Survey of Huangqi Lake

Huangqi Lake is one of the three large lakes in the western portion of the Nei Mongol Autonomous Region. It is situation approximately 5 km northeast of the town of Togrog Ul in Qahar Right Wing Front Banner, at 40°45'N and 113°10'～23'E. The lake is at an elevation of 1,266 m above sea level, it is 18 km long east to west and it is 6 km wide north to south. At present the average depth is about 2 m and the total surface is 90 km^2.

Huangqi Lake is located in the middle of the Huangqi Lake Basin, which is a rift basin covering an area of 290 km^2. This is an area of typical continental climate, having cold temperatures, aridity and windiness as its major characteristics. The mean annual atmospheric temperature is around 4.7°C, annual precipitation averages 390.6 mm and annual evaporation averages 1,953.7 mm.

The soil mantle of Hunagqi Lake Basin is composed of castanozem, meadow soil, bog soil, saline-alkali soil and original fluvisol. The soil solution is slightly alkaline, having a pH of around 8.5. The natural vegetation is composed of conifers, droseraceae, cryptophyceae, ascomycetes, grasses and thyme grassland.

Altogether, there are 21 rivers and gullies that flow into Huangqi Lake. The major perennial rivers are the Bawang He, the Quanyu Lin He, the Xiao Lama He and the Da Hewan He. The others are all seasonal rivers.

Huangqi Lake is surrounded by 8 communes having a total population of about 120,000 people and around 500,000 mu of cultivated land. The primary crops are wheat, naked oats, potatoes, millet and broomcorn millet. Economic crops include beets, gourds and sunflowers.

The fishing industry on Huangqi Lake was developed after liberation. In 1950 crucian carp were discovered, in 1956 a state-operated fishing ground was established and in 1958 an artificial fishery was started and stocked with black carp, chub, variegated carp, and other varieties of carp. Prior to 1967 the annual output of fish was 700~1,000 tons, in 1970 it was 308 tons and by the beginning of 1972 all types of fish had died out.

II. An Initial Evaluation of Water Quality in Huangqi Lake

This evaluation is based on survey data from 1974 and 1981.

A. Evaluation Methods

1. Site Layout and Sampling

The layout of survey sites and the sampling periods in the two surveys were identical. Altogether, three sites numbered 1, 2 and 3, were set up (see Map 1). In each of the surveys water was collected twice, once in the dry season (May) and once in the rainy season (September). At each site upper and lower water levels were sampled and 22 items, including pH levels, overall alkalinity, chloride levels and so forth were measured. For the year a total of 264 data measurements were obtained.

Map 1. Geographical Position and River System of Huangqi Lake

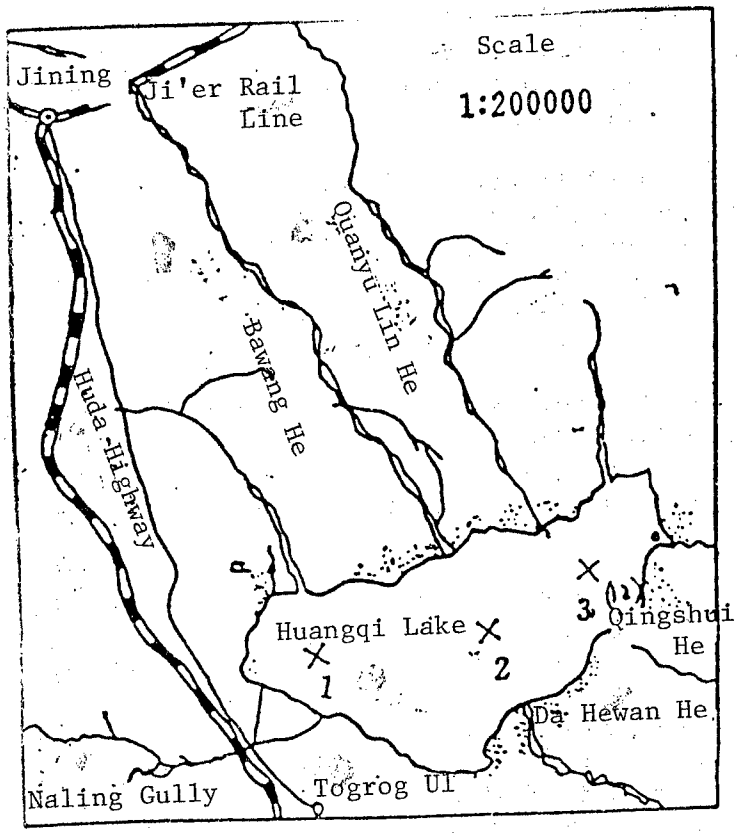

Table 1. Annual Mean Values of Each Parameter

Annual Mean Value		pH Level	Oxygen Solution	Amount of Chemical Oxygen Depletion	Chloride Level	Overall Alkalinity	Fluoride Level	Lead	Copper	Mercury	Zinc	Arsenic	Phenol
Site 1	1974	9.3	5.3	23.59	4375.1	46.3	2.8	0.003	0.03	0	0.05	0.025	0
	1981	9.31	9.48	10.80	3340	39.6	1.69	0.013	0.027	0.0058	0.062	0.031	0.0055
Site 2	1974	9.27	5.4	23.51	3706	43.9	4.85	0.025	0.05	0	0.04	0.02	0
	1981	9.31	8.21	10.92	3015	36.9	1.84	0	0.032	0.005	0.051	0.024	0.0054
Site 3	1974	9.3	6.43	24.88	4878.5	47.6	4.85	0.013	0.05	0	0	0.015	0.00003
	1981	9.3	8.03	10.69	3284	38.3	1.97	0.013	0.037	0.0048	0.04	0.028	0.0027

(1) In this table all units are expressed as mg/l, with the exception of pH (nondimensional) and overall alkalinity (expressed in mg-equivalents/l); (2) The annual mean value for 1974 is taken from data compiled by the "Nei Mongol Huangqi Lake Survey Team" in that same year. The annual mean values for 1981 were provided from the list reported by Wumeng Environmental Protection Monitoring Station and Jining Environmental Protection Monitoring Station.

Table 2. Fractional Indices for Each Parameter

Annual Mean Value		pH Level	Oxygen Solution	Amount of Chemical Oxygen Depletion	Chloride Level	Overall Alkalinity	Fluoride Level	Lead	Copper	Mercury	Zinc	Arsenic	Phenol
Site 1	1974	1.53	0.675	4.72	1.25	1.54	2.8	0.03	3	0	0.5	0.25	0
	1981	1.54	0	2.16	0.9255	1.32	1.69	0.13	2.7	11.6	0.62	0.31	0.11
Site 2	1974	1.51	0.631	4.5	1.06	1.47	4.85	0.25	5	0	0.4	0.2	0
	1981	1.54	0	2.18	0.86	1.23	1.84	0	3.2	10	0.51	0.24	0.11
Site 3	1974	1.53	0.392	4.96	1.39	1.59	4.85	0.13	5	0	0	0.15	0.006
	1981	1.52	0	2.14	0.94	1.28	1.97	0.13	3.7	9	0.4	0.28	0.54
Fishery water quality Standards		6.5~8.5	>4	5**	3500*	30*	1.0	0.1	0.01	0.0005	0.1	0.1	0.005

Entries marked with an asterish refer to "Nei Mongol Huangqi Lake Joint Survey Team" data; entries marked with a double asterisk refer to Japan's Water Quality Standards for Lake Aquatic Production--see Wu Jinyi [0702 6930 6230], "Environmental Engineering," pp 234 (1980 Hebei People's Publishing House); all other entries refer to Fishery Water Quality Standards TJ35~79 (trial).

2. Selection of Parameters

Taking into consideration that Huangqi Lake is one of the closed lakes on the Nei Mongol Plateau, and that it has characteristics of salinity and excess alkalinity, we decided on a selection of 12 data measurements, as follows: pH levels, oxygen solution, amount of chemical oxygen depletion, chlorides levels, overall alkalinity and levels of fluoride, lead, copper, mercury, zinc, arsenic and phenol.

For the annual mean C_{λ}' (Concentration Index] values, see Table 1. These are the mean values of the four samples taken at all the sampling sites (twice each year from both upper and lower levels).

3. Using the calculation method from the Index of Lake Water Quality and Pollution in the "Summary of Environmental Quality Evaluation Methods,"[1] we calculated the fractional index for each pollutant. For these results, see Table 2.

4. Calculation of the Composite Index of Pollutants

Using the "vector" model suggested by Comrades Shen Baocheng [3947 5508 6134] and Xu Guoyi [1776 0948 5030], we calculated the composite index for each sampling site.[2] For these results, see Table 3.

Table 3. Composite Index

Survey Site	1974	1981
Site One	2.16	2.44
Site Two	2.57	2.31
Site Three	2.68	2.21
Mean	2.47	2.32

5. Evaluation Results

On the basis of the previous index classification, it can be seen from Table 2 that data with a fractional index between 1.0~4.0 include pH level, chlorides, overall alkalinity, quantity of chemical oxygen depletion, fluoride and copper. The indication is that the data concerned have reached levels of "moderate pollution" or "relatively serious pollution." Those individual index figures that are higher than 4.0 indicated that a "serious pollution" level has been reached. From Table 3 it can be seen that the composite indices are all between 2.0 and 4.0, indicating that they have reached the level of "relatively serious pollution." The 1981 index numbers are a little lower than those for 1974, illustrating that water quality had improved slightly in 1981.

B. Analysis of the Evaluation Results

Why has the water quality of Huangqi Lake deteriorated? Why have the fish died out? At this late date, why has there been no basic improvement? The reasons are as follows:

In 1974 the Nei Mongol Huangqi Lake Joint Survey Team conducted a geological and geomorphological investigation of Huangqi Lake water quality and of the Huangqi Lake Basin. Their conclusion was that there is a first source of pollution influencing the quality of water in Huangqi Lake (this refers to rocks and minerals, soil vegetation cover, surface water, groundwater and natural precipitation) and a second source of pollution (this refers to the waste water discharged by the factories, hospitals and railroad units of Jining City and the town of Togrog Ul). Of these two, the first source of pollution is the primary and intrinsic source, and the second source of pollution is the secondary and extrinsic source. Of greatest significance is that the primary source of pollution has changed notably. Prior to the 1950s the Huangqi Lake Basin was a grass farm with some grazing capacity. From an ecological point of view, Huangqi Lake and Huangqi Lake Basin constitute an ecoloigcally balanced water-grassland system. Beginning in the 1950's owing to the implementation of the policy of "emphasizing agriculture," grass farming was progressively replaced by agriculture. In this process, the water quality of Huangqi Lake underwent major changes. The most striking change was the increase in salinity and alkalinity. For example the pH value increased from 8.8 in 1962 to 9.0 in 1972 and 9.3 in 1974. Overall water hardness rose from 21 degrees in 1962 to 33 degrees in 1972 and 47 degrees in 1974. Overall alkalinity rose from 16 mg-equivalents/l in 1964 to 32 mg-equivalents/l in 1972 and 45 mg-equivalents/l in 1974. The salt content rose from 7,997 mg/l in 1972 to 11,685 mg/l in 1972. Why did the salinity and alkalinity rise? It is because grass farm was lost, and thus weeds for soil and water conservation were lost. Whenever a flood breaks out or when blowing sand fills the air in the local mountains, large quantities of sediment are deposited in the lake. This sediment has a high background value of salt and alkali. Second, when the grass farm was lost, weeds that absorbed a certain amount of salt and alkali were lost, and this was tantamount to increasing the salt and alkali in the soil. The deposit of sediment into the lake also amounted to an increase in the salt and alkali in the lake water. Third, 50 to 60 tons of pesticides and nearly 1,000 tons of chemical fertilizers must be applied to the farmland surrounding the lake every year. In addition to directly harming the fish, this also can increase the alkalinity of the soil. With the deposit of sediment into the lake, the alkalinity of the lake water is likewise raised. Therefore, replacing grass farming with agriculture results in serious soil erosion, a year by year decline in crop output, a progressive increase in the salinity and alkalinity of the lake water and complete extinction of the fish.

III. A Few Suggestions for Bringing Huangqi Lake Under Control

By way of the water quality evaluation, the following ideas for control are advanced:

1. In order to restore the damage already done to the ecologically balanced water-grassland system, to reduce pesticide and chemical fertilizer pollution and to reduce the salinity and alkalinity of the lake water, throughout the Huangqi Lake Basin we must implement the policy that "promotes animal husbandry through forestry and stresses animal husbandry." We should change all of the agricultural teams in the Huangqi Lake region into animal husbandry teams and transform all of the farmland into grass farms and tree farms.

2. In order to reduce the salinity and alkalinity of the lake water and reduce harmful industrial toxins, we must cultivate a large quantity of aquatic plants in Hunagqi Lake. We should continue to carry out the original plan for reed cultivation because aquatic plants and reeds can absorb a certain amount of salt, alkali and industrial toxins.

3. In order to reduce the effects of the second source of pollution on Huangqi Lake, we must control the industrial waste water of Jining City and Togrog Ul. Of these, we should place an emphasis on the waste water from Jining City. It is proposed that we build an artificial oxidation pond in the vicinity of Wujia Cun Reservoir (all of the city's major waste water first enters this reservoir and then goes into the Bawang He) to carry out biological purification on the waste water flowing into the Bawang He.

4. At present we must continue to carry out breeding experiments. In addition to conducting "cage culture" experiments, we must also expand to "pilot trials." We should also increase the varieties of fish in these experiments.

FOOTNOTES

1. The Chinese Institute of Environmental Science Commission for Evaluation of Environmental Quality, "Summary of Environmental Quality Methods," 1981, pp 52-59.

2. Shen Baocheng and Xu Guoyi, "Environmental Science," (4), 1981, pp 57-61.

12510
CSO: 4008/327

^{3}H IN EAST CHINA SEA

Beijing HAIYANG KEXUE [JOURNAL OF MARINE SCIENCE] in Chinese No 4, Jul 84 pp 20-22

[Article by Kang Xinglun [1660 5281 0243] et al., of the Research Institute of Oceanography, Chinese Academy of Sciences: "Determination of ^{3}H in East China Sea"]

[Summary] There are three sources of Tritium, ^{3}H, cosmic ray and atmospheric action, the test of thermonuclear weapons, and waste discharge from nuclear power facilities: the accumulation of all three has caused the ^{3}H content of rainwater to reach 100-1,000 T.U. In June 1978, samples of sea water in East China Sea were taken and sealed in plastic containers for analysis after the ship returned to a land-based laboratory. A map showing the density distribution of ^{3}H in the sampled area, varying from 12 to 30 T.U., is presented. There is also a graph showing its vertical distribution from the water surface to a depth of 2,000 meters. The paper suggests that the fact that the samples were taken during a rainy season may have influenced the results of the study. The method of distilling and analyzing the sea water samples is introduced in some detail.

6248
CSO: 4009/27

KL TRANSFORM OF REMOTE SENSING IMAGES OF BOHAI BAY

Beijing HAIYANG XUEBAO [ACTA OCEANOLOGICA SINICA] in Chinese Vol 6 No 4, Jul 84 pp 479-484

[Article by Xu Dianyuan [6079 3013 0337] et al., of the Research Institute of Geography, Chinese Academy of Sciences, Beijing: "KL Transform of Remote Sensing Images of Bohai Bay in the Vicinity of the Haihe Estuary and Its Use in Interpreting Sea Water Pollution"]

[Summary] An area of about 960 km^2 of Bohai near the estuary of Haihe is selected to study the efficacy of using KL transform of remote sensing images to interpret the extent of sea water pollution. Remote sensing is a fast and economical technique of monitoring pollution of the sea, utilizing the spectral difference between clean and polluted water. The KL transform process of the remote sensing images on a computer and the method of mathematical analysis of images are briefly introduced. The paper concludes that with a computer to process remote sensing images, it is possible to combine digital data analysis and image interpretation to produce quantitative information of the ocean environment and the degree of pollution of a given area of the sea. The land origin pollutants of COD, amino nitrogen, phosphates, and petroleum are found to be more dense in the shore region and distributed in a belt shape area of south-north direction. Oil pollution in the harbors, from the ships, and near the oil wells are also said to be visible on the images.

This paper was received for publication on 13 May 1983.

6248
CSO: 4009/15

HEAVY METAL POLLUTION OF CHANGJIANG ESTUARY

Beijing HAIYANG XUEBAO [ACTA OCEANOLOGICA SINICA] in Chinese Vol 6 No 4, Jul 84 pp 453-460

[Article by Zhuang Guoshun [8369 0948 7311] et al., Institute of Oceanographic Research No 3, State Bureau of Oceanography, Xiamen: "Solid-Liquid Boundary Process of Heavy Metals in Changjiang Estuary: III. Dynamics of Pb, Cu, Cd Absorption by Hydrated Iron Oxide"]

[Summary] Certain environmental conditions of the Changjiang estuary are simulated to study the rate of absorption of various systems under different temperature conditions. Consequently, the activation absorption energy for Pb and Cu are determined to be 7 and 11 Kcal/gram molecule, respectively. The absorption rate of hydrated iron oxide for the three metals is found to be Pb > Cu > Cd, in line with the constants for thermodynamic balance. Results of this experiment verified the theory that surface exchange absorption is a dynamically controlled process of solid-liquid boundary reaction. This finding provides a basis for theoretical interpretation of the survey data of the Changjiang estuary. The method of calculating the rate of boundary absorption and the required activation absorption energy is discussed at some length.

This paper was received for publication on 10 May 1982.

6248
CSO: 4009/15

FLUORIMETRIC DETERMINATION OF TRACE AEPT DESCRIBED

Changchun FENXI HUAXUE [ANALYTICAL CHEMISTRY] in Chinese No 8, 20 Aug 84 pp 723-725

[Article by Bao Hongjie [0545 3163 2638], Yan Kegang [7346 0344 3263] and Liu Enwen [0491 1869 2429]: "Fluorimetric Determination of Trace Aminoethyl Phosphonothiolates"]

[Summary] A method for the fluorimetric determination of trace aminoethyl phosphonothiolates (AEPT) in wastewater is described. The technique for combining the ion exchange method with a chemical reaction on the ion-exchange column was used to concentrate and separate AEPT in wastewater. AEPT adsorbed on the ion-exchange column can react with silver and fluoride ions to form phosphonofluoridates which can be eluted with deionized water. Peroxyphosphorus acid formed in the reaction of phosphonofluoridate with sodium perborate and oxidize indole to give a highly fluorescent indigo white. The fluorescence of the sample is measured at 360 nm (EX) and 470 nm (EM) respectively with the limit of determination of 0.01 μg/ml.

9717
CSO: 4009/71

MERCURY IN AIR DETERMINED RAPIDLY

Changchun FENXI HUAXUE [ANALYTICAL CHEMISTRY] in Chinese No 7, 20 Jul 84 pp 564-568

[Article by Pang Shuwei [1690 0647 5633], Qiu Guangkui [6726 0342 5525] and Xu Liangcai [1776 5328 2088], all of the Institute of Environmental Chemistry, Chinese Academy of Sciences: "Selective Absorption Tube and Cold-Atomic Absorption Technique for Rapid Determination of Mercury Species in Air"]

[Summary] A method is described for the determination of the total gaseous mercury and dimethyl-mercury in air at concentrations ranging from about 0.5 ngm^{-3} to 10 μgm^{-3}. The method is based on the collection of mercury species on gold-coated lake sand and/or silver spiral filament tube followed by detection with a cold-atomic absorption mercury analyzer. The method is simple and rapid. The absolute detection limit is 0.5 nm of mercury, and the relative standard deviation of the signal corresponding to 20 ng of mercury is 6 percent (n=12). The method is suitable for the determination of mercury species in clean air or polluted air controlled by the sampling time. This method has been used in studying the distribution of atmospheric mercury species near ground around a chloro-alkali plant, and in measuring the background concentration at famous scenic spots in Beijing.

MICRODETERMINATION OF MERCURY (II) TECHNIQUE DESCRIBED

Changchun FENXI HUAXUE [ANALYTICAL CHEMISTRY] in Chinese No 7, 20 Jul 84 pp 611-613

[Article by Zhang Chunxu [1728 2504 3563], Chen Jinsheng [7115 6651 3932] and Tong Yunkun [0157 0061 3824], all of the Department of Chemistry, Nankai University: "Kinetic Determination of Mercury (II) in Wastewaters with Ion-Selective Electrode"]

[Summary] A technique has been offered for the microdetermination of mercury (II) in wastewaters based on the catalysis of the following reaction by the mercury (II) ion:

$$Fe(CN)_6^{4-} + 3(3,10\text{-phenanthroline}) \rightleftarrows ferroin^{2+} + 6CN^-$$

The cyanide ion released in the reaction is then determined by a cyanide ion-selective electrode. The optimal conditions for the replacement reaction and the subsequent measurement of mercury (II) of about 0.1 ppm have been reported. The calibration curve of the potential vs the logarithm of the mercury (II) concentration is linear over the range of 0.1 to 2.0 μg/15 ml.

9717
CSO: 4009/72

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TITLE: "A Simplified Method for the Preparation and Purification of Plasmid DNA"

SOURCE: Beijing SHENGWUHUAXUE YU SHENGWUWULI JINZHAN [BIOCHEMISTRY AND BIOPHYSICS] in Chinese No 4, Aug 84 pp 64-67

ABSTRACT: Since the demand for plasmid DNA has increased by leaps and bounds, there have been many reports of techniques capable of producing it efficiently, simply, and at an acceptable degree of purity. Techniques such as CsCl density gradient supercentrifuge are now commonly used in foreign laboratories; these are seldom adopted in China, however, due to scarcity of equipment they require. The authors compared several other techniques and found them to have respective advantages and disadvantages. Finally, they made improvements to the experimental conditions of the L.P. Elwell method before filtering the extracted plasmid DNA with Sephacryl S-100. With this technique they are able to obtain highly pure plasmid DNA at a high rate of production and free of chromosome DNA and RNA. The seed E.coli which contains pAT-153 plasmids is supplied by the Research Institute of Microbiology, Chinese Academy of Sciences; names of foreign manufacturers of other supplies are given. The procedure, which has become one of the routine methods of extracting plasmid DNA in the authors' laboratory, is described and discussed.

This paper was received for publication on 7 August 1983.

6248
CSO: 4009/26

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TITLE: "Purification of Plasmid DNA with Column Chromatography"

SOURCE: Nanjing NANJING DAXUE XUEBAO (ZIRAN KEXUE BAN) [JOURNAL OF NANJING UNIVERSITY (NATURAL SCIENCES EDITION)] in Chinese No 3, 1984 pp 515-523

TEXT OF ENGLISH ABSTRACT: A simple, effective procedure for the purification of plasmid DNA is described. According to the procedure a plasmid DNA--pBR 322 and pAt 153--was obtained. The frequency of transformation of genetic markers of resistant antibiotics has been determined using E. coli C_{600} and HB 101 as the recipient cells respectively.

9717
CSO: 4009/80

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TITLE: "An Electron Microscopic Study of Platelet Morphology and Aggregation Pile Before and After Flight in Jet Fighter Pilot"

SOURCE: Beijing JIEFANGJUN YIXUE ZAZHI [MEDICAL JOURNAL OF CHINESE PEOPLE'S LIBERATION ARMY] in Chinese No 5, 20 Oct 84 pp 372-375

TEXT OF ENGLISH ABSTRACT: The platelet morphology and aggregation pile were studied with an electron microscope before and right after flight in 38 jet fighter pilots, consisting of a group of 8 with abnormal ECG and an average age of 36. Also tested was a control group of 30 with normal ECG and an average age of 31. The percentage of various types of platelets, including round-, tree-, transitional-, plate- and breakdown-type, and aggregation piles were calculated. Before flights, there were no statistically significant differences in the types as well as in the aggregation piles mentioned above between the two groups ($p > 0.05$). A significant increment of aggregation piles right after flights was shown in both groups ($p < 0.01$), with a more marked change in the control group than in the ECG-abnormal group ($p < 0.01$). On the other hand, platelets in both groups showed no significant changes in their morphological types right after flights ($p > 0.05$).

9717
CSO: 4009/77

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TITLE: "A Structured Microprogramming Language SMPL"

SOURCE: Beijing JISUANJI XUEBAO [CHINESE JOURNAL OF COMPUTERS] in Chinese No 5, Sep 84 pp 321-329

TEXT OF ENGLISH ABSTRACT: A Pascal-like high-level microprogramming language, SMPL, is proposed. In order to fit the microarchitecture and microprogramming, some of Pascal's data structures and statement types are deleted and some microlanguage features are added. The methodology of designing a well-structured and machine independent high-level microprogramming language is discussed and the basic syntactic description of SMPL is given. A cross microcompiler for SMPL is implemented on NOVA-3. The result of compiling the emulation microprograms for the basic instruction set of IBM System/370 shows that the efficiency of the object microcode produced by the SMPL microprograms is very close to that produced by the IBM micro-assembly language microprograms.

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TITLE: "B-Adjacent Chip Error Correcting Codes"

SOURCE: Beijing JISUANJI XUEBAO [CHINESE JOURNAL OF COMPUTERS] in Chinese No 5, Sep 84 pp 366-374

TEXT OF ENGLISH ABSTRACT: This paper presents a class of single B-adjacent chip error correcting codes suitable for error correcting of LSI memory chips. By employing these codes, the error correcting ratio is $\frac{2^b-1}{2b}$. These codes can also be used to correct any error occurring on a single chip.

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TITLE: "The Experimental Analysis and Improvement of the Uncertainty of the K-means Method"

SOURCE: Beijing JISUANJI XUEBAO [CHINESE JOURNAL OF COMPUTERS] in Chinese No 5, Sep 84 pp 390-398

TEXT OF ENGLISH ABSTRACT: An experiment on the uncertainty of the K-means method is described in this paper. A data set of two-dimensional 210-point samples and the IRIS data set of four-dimensional 150-point patterns are analyzed. In order to compare different results of the experiment, three approaches for selecting initial centers of classes are considered. In the comparison process, three performance indexes are employed as criteria of the results of the K-means method. A new clustering method, OUPIC, is developed.

9717
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TITLE: "Dynamic Observation on Early Artificial Abortions with B-Mode Sonograph"

SOURCE: Shijiazhuang ZHONGHUA WULI YIXUE ZAZHI [CHINESE JOURNAL OF PHYSICAL MEDICINE] in Chinese No 3, 25 Sep 84 pp 129-132

TEXT OF ENGLISH ABSTRACT: A B-mode sonographic dynamic study of 23 cases of early pregnancies terminated with 16, 16-Dimethyl-trans-Δ^2PGE$_1$, methyl estes is reported. A total of 140 sonographies were performed. The characteristics of sonographies of early abortions are as follows: the change in shape of the gestation sac, the lowering of the location of the sac, the failure of the sac to grow, the blighting of the ovum, the dilated cervical os, etc. 86.67 percent (13/15) of the abortions showed such changes of the sac as elongated shape, irregularities of the borderline, unclear or empty in appearance, etc. It is suggested that the lower location of the sac represents the abortion process ahd the dilating cervical os may be a sign of inevitable abortion.

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TITLE: "An Experimental Study on Canine Gastric Bleeding Treated by Nd:YAG Laser Photocoagulation"

SOURCE: Shijiazhuang ZHONGHUA WULI YIXUE ZAZHI [CHINESE JOURNAL OF PHYSICAL MEDICINE] in Chinese No 3, 25 Sep 84 pp 157-160

TEXT OF ENGLISH ABSTRACT: A Nd:YAG laser apparatus developed by our laboratory was applied to the study of photocoagulation hemostasis of experimental gastric bleeding in 10 dogs. The results showed that with the irradiation of the Nd:YAG laser (power of 40 or 50W and pulse of 0.5 or 1s), the efficiency of hemostasis reached 83.3 percent. The highest efficiency was reached by the power at 50W and pulse of 0.5s. The average irradiation time of photocoagulation was 5.8s. The inappropriate prolongation of laser irradiation time resulted in gastric perforation. By using the laser power of 50W and pulse of 0.5s, the irradiation time for initiating gastric perforation appeared at 36s, which was the longest and about six times that of photocoagulation hemostasis. Histologic examinations indicated that the histologic legions caused by irradiation of power of 50W and pulse of 0.5s involved the submucosa only. It was concluded that the treatment of gastric bleeding with laser irradiation of 50W power and 0.5s pulse is effective and safe, if the frequency of irradiation is strictly controlled.

9717
CSO: 4009/47

Medicine

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TITLE: "Purification and Characterization of DNA Polymerase α From Ehrlich Ascites Cells"

SOURCE: Beijing ZHONGGUO YIXUE KEKUEYUAN XUEBAO [ACTA ACADEMIAE MEDICINAE SINICAE] in Chinese No 4, 15 Aug 84 pp 240-242

ABSTRACT: This paper reports successful purification of DNA polymerase of Ehrlich ascites cells over 100 folds with DEAE-cellulose chromatography, phosphocellulose chromotography, and Sephadex G-100 gel filtration. Contaminated DNA and DNase were not found when the product was tested with fluorometric and isotope methods. The molecular weight of the product is about 130,000; it is inhabited by 1mM of N-ethylmaleimide. Activated DNA and not natural DNA is the preferred template. The process of extracting and purifying the DNA polymerase α and the physical and chemical characteristics of the product are described.

This paper was received for publication on 27 June 1983.

6248
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Medicine

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TITLE: "Cloning of Adr HBV Genome and Its Surface Antigen Gene"

SOURCE: Beijing ZHONGGUO YIXUE KEXUEYUAN XUEBAO [ACTA ACADEMIAE MEDICINAE SINICAE] in Chinese No 4, 15 Aug 84 pp 252-254

ABSTRACT: This paper reports the successful extraction and purification of HBV-DNA from the serum of a carrier in a high HBV area of North China; it belongs to the adr subtype, which is the dominant type in China, especially N. China. Its clone line, given the name of pHBV-NC, was established by reconstruction, cutting, ligating, and hybridization; with electron microscopy the clone was proved to contain a complete HBV-DNA genome. After determining the orientation of the HBV-DNA, a subclone, containing surface antigen gene only, was constructed by cutting off a part of the HBeAg; it was given the name of pHBV-NCsAg. The reconstructed plasmid pHBV-NC is important for genetic engineering research of human hepatitis B and is also the essential material for preparing HBV vaccine.

This paper was received for publication on 23 November 1983.

6248
CSO: 4009/28

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TITLE: "Histopathological Study of Skin Radiation Injury"

SOURCE: Beijing ZHONGHUA BINGLIXUE ZAZHI [CHINESE JOURNAL OF PATHOLOGY] in Chinese No 1, 30 Mar 84 pp 49-51

TEXT OF ENGLISH ABSTRACT: Histopathological study of 49 excised specimens of skin radiation injury were reported. Hypertrophic changes including hyperkeratosis, parakeratosis, thickened prickle layers and elongation of rete pegs and/or degenerative changes such as dyskeratosis, dysplasia and disappearance of rete pegs were found in the epidermis. Hyalinization of collagen fibers, hyperplasia and fragmentation of elastic fibers, thickened arterial and venular walls and partial or complete obstruction of small blood vessels could also be obtained in the dermis. The skin appendages were atrophic or had disappeared. No malignant changes were discovered in the 49 cases. The pathological changes in relation to the clinical symptoms and signs and the effectiveness of the surgical treatments are discussed.

9717
CSO: 4009/78

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TITLE: "MBE GaAs Single Crystal Films"

SOURCE: Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese No 2, Mar 84 pp 225-229

TEXT OF ENGLISH ABSTRACT: GaAs films have been prepared by molecular beam epitaxy. Undoped MBE GaAs is n-type with net carrier concentration (1.8-8) x 10^{16} cm^{-3} and mobility 3000-5000 $cm^2/V \cdot s$ at room temperature. Its highest mobility is 5466 $cm^2/V \cdot s$ (n = 1.93 x 10^{16} cm^{-3}) with a corresponding mobility of 1.59 x 10^4 $cm^2/V \cdot s$ at 77K. Properties of high impurity level films have been studied with cathodoluminescence and SIMS.

9717
CSO: 4009/63

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